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(54) **Engine cooling system.**

(57) An engine cooling system comprises a cooling water circulation circuit (1) interconnecting an engine body (E) and a radiator (R), a bypass circuit connected to the cooling water circulation circuit (1) to bypass the radiator (R), an electric-powered water pump (4) disposed in the cooling water circulation circuit (1) adjacent an engine inlet, a flow rate control valve (3) for controlling the flow rate of cooling water flowing through the radiator (R), an engine outlet water temperature detector (15), an engine inlet water temperature detector (16), and means for controlling the operation of the water pump (4) in accordance with at least the engine outlet water temperature and controlling the operation of the flow rate control valve (3) in accordance with at least the engine inlet water temperature to thereby properly control the temperature of the cooling water in accordance with the operational condition of the engine (E). In a knocking mode a target engine outlet water temp rature for controlling the pump (4) may be reduced to reduce the temp rature difference between the engine inlet and outlet temperatures, and in a post-stoppage mode the pump may be controlled by an open loop based on the ngine outl t water temp rature. The control valve (3) may be controlled on the basis of the engine inlet or outlet water temperatures depending on the water temperature and engine load.

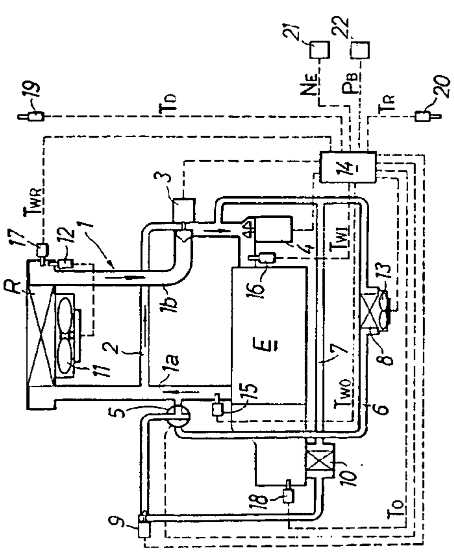

FIG.1

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The present invention relates to an engine cooling system in an internal combustion engine.

There is a conventionally known engine cooling system having an electric-powered variable displacement water pump provided adjacent an engine inlet in a cooling water circulation circuit interconnecting an engine body and a radiator. Such an engine cooling system is known, for example, from Japanese Patent Application Laid-open No.2418/83. Further, an engine cooling system comprising a variable displacement control valve provided in the cooling water circulation circuit to adjust the amount of cooling water flowing through the engine by controlling the opening degree of the control valve is also known, for example, from Japanese Patent Publication No.571/89.

To precisely control the operation of the water pump to provide a cooling water temperature suitable for the operational condition of the engine by the cooling system disclosed in Japanese Patent Application Laid-open No.2418/83, it is desired to effect a feed-back control of the operation of the water pump in accordance with the engine water temperature. In this case, the rapid warming-up of the engine can be achieved by effecting the feed-back control of the water pump, so that the amount of cooling water flowing through the engine body is extremely small during warming-up of the engine. However, a value detected by a water temperature detector is incorrect due to the fact that the amount of cooling water flowing through the engine body during warm-up is extremely small. For this reason, in the engine cooling system using the feed-back control, it is difficult to increase the engine water temperature up to a desirable value, and the engine water temperature may be increased more than necessary, in some cases.

The present inventors have found that for the purpose of avoiding the generation of engine knocking, it is effective to reduce the difference between an engine inlet water temperature and an engine outlet water temperature. However, in such a feed-back control as described above, it is difficult to optimally control the difference between the engine inlet water temperature and the engine outlet water temperature to avoid the generation of knocking.

In order to shorten the warming-up time and to avoid an over-cooled state, a target value for the engine outlet water temperature may be previously set at a relatively high level, and the opening degree of the control valve may be controlled, so that the engine outlet water temperature reaches the target value. In the prior art system disclosed in the Japanese Patent Publication No.571/89, in a normal operational condition, the opening degree of the control valve is controlled in accordance with the engin load and the engine rate of revolution number, so that the temperature of a cylinder wall is in a predetermined range, on the one hand, and during warming-up of the engine, the opening degree (the fully closed state) of the control valve is controlled so that the engine outlet water temperature is about 120°C, on the other hand. However, when the amount of the cooling water is controlled with only the engine outlet water temperature, it is possible that the engine will become overheated. In the above prior art system, the temperature of the cylinder wall is detected directly, and the opening degree of the control valve is corrected by such detected value, so that the temperature of the cylinder wall is maintained within the predetermined range. For this reason, the arrangement of a control circuit is complicated.

Accordingly, it is an object of the present invention to provide an engine cooling system wherein the temperature of the cooling water can be controlled properly in accordance with the operational condition of the engine by a simple construction.

To achieve the above object, according to a first aspect and feature of the present invention, there is provided an engine cooling system comprising a cooling water circulation circuit interconnecting an engine body and a radiator, a bypass circuit connect to the cooling water circulation circuit to bypass the radiator, an electric-powered variable displacement water pump disposed in the cooling water circulation circuit adjacent an engine inlet, a flow rate control valve for controlling the flow rate of cooling water flowing through the radiator, an outlet water temperature detector for detecting the engine outlet water temperature in the cooling water circulation circuit, an inlet water temperature detector for detecting the engine inlet water temperature in the cooling water circulation circuit, and a control means for controlling the operation of the water pump in accordance with at least the engine outlet water temperature and controlling the operation of the flow rate control valve in accordance with at least the engine inlet water temperature.

With the above construction, the cooling water of an optimal amount suitable for the engine outlet water temperature is permitted to flow through the engine body, and moreover, the amount of cooling water flowing through the radiator and the amount of cooling water flowing through the bypass circuit can be controlled to insure an appropriate amount of the cooling water.

According to a second aspect and feature of the present invention, there is provided an engine cooling system comprising a cooling water circulation circuit interconnecting an engine body and a radiator, an electric-powered variable displacement water pump disposed in the cooling water circulation circuit adjacent an engine inlet, a water temperature detector for detecting the engine water temperature, and a control means for controlling the operation of the water pump in such a manner to switch-over a feed-back control according to the engine water temp rature and an open loop control from one to another in accordance with the operational condition of the engine.

With the above construction, even if the engine is in an operational condition in which a value detected by the water temperature detector is incorrect, an appropriate amount of the cooling water can be permitted to flow through the engine body, contributing to the proper control of the amount of the cooling water.

According to a third aspect and feature of the present invention, there is provided an engine cooling system comprising a cooling water circulation circuit interconnecting an engine body and a radiator, an electric-powered variable displacement water pump disposed in the cooling water circulation circuit adjacent an engine inlet, an engine outlet water temperature detector for detecting the engine outlet water temperature, a knocking detector for detecting the knocking of the engine, and a control means capable of performing a feed-back control of the water pump in accordance with the engine outlet water temperature and reducing the target value for the feed-back control, when engine knocking is detected.

With the above construction, the difference between the engine inlet water temperature and the engine outlet water temperature can be decreased to promptly eliminate the knocking which has been genrated.

According to a fourth aspect and feature of the present invention, there is provided an engine cooling system comprising a cooling water circulation circuit interconnecting an engine body and a radiator, a variable flow rate control valve mounted in the cooling water circulation circuit, an engine inlet water temperature detector for detecting the engine inlet water temperature, an engine outlet water temperature det ctor for detecting the engine outlet water temperature, and a control means capable of being switched over between a state for controlling the opening degree of the variable flow rate control valve to bring the engine outlet water temperature into a target outlet t mperature, when the engine inlet water temperature is in a low water temperature region, and a state for controlling the opening degree of the variable flow rate control valve to bring the engine inlet water temperature into a target inlet temperature, when the engine inlet water temperature is in a high water temperature region.

With the above construction, it is possible to shorten the warming-up time and avoid over-cooling by a simple construction.

The above and other objects, features and advantages of the invention will become apparent from the following description of preferred embodiments, given by way of example only, taken in conjunction with the accompanying drawings, in which:

Fig.1 is an illustration of the entire engine cooling system according to a first embodiment of the present invention;

Fig.2 is a flow chart illustrating a procedure for controlling the operation of a water pump;

Fig.3 is a diagram illustrating a map of duty ratios established for the procedure in an open loop control;

Fig.4 is a diagram illustrating a map of target outlet water temperatures established for the procedure;

Fig.5 is a diagram illustrating a map of reference duty ratios established for the procedure;

Fig.6 is a flow chart illustrating a procedure for controlling the flow rate control valve;

Fig.7 is a diagram illustrating a map of target inlet water temperatures established for the procedure;

Fig.8 is a diagram illustrating a map of gain established for the procedure;

Fig.9 is a diagram illustrating a fuel consumption rate characteristic based on the temperature of cooling water;

Fig.10 is a graph illustrating a knocking generation ignition timing characteristic based on the temperature of cooling water;

Fig.11 is an illustration of the entire engine cooling system according to a second embodiment of the present invention;

Fig.12 is a flow chart of a main routine showing a procedure for controlling the operation of a water pump;

Fig.13 is a flow chart illustrating a subroutine in a knock judging mode;

Fig.14 is a flow chart illustrating a subroutine in a post-stoppage mode of the engine;

Fig.15 is a diagram illustrating a map of operative region and inoperative region established after stoppage of an engine;

Fig.16 is a diagram illustrating a map of duty ratio established in an open loop control after stoppage of the engine;

Fig.17 is an illustration of the entire engine cooling system according to a third embodiment of the present invention;

Figs.18 to 21 are continuing portions of a flow chart illustrating a procedure for controlling a variable flow rate control valve;

Fig.22 is a first map of the relationship to cause the flag to be established in accordance with the engine rate of revolution number and the engine intake pressure;

Fig.23 is a second map of the relationship to cause the flag to be established in accordance with the engine revolution number and the engine intake pressure;

Fig.24 is a graph illustrating the net fuel consumption rate based on the engine outlet water temperature;

Fig.25 is a graph illustrating the indicated specific fuel consumption rate according to the engine outlet water temperature;

Fig.26 is a graph illustrating the friction horsepower according to the engine outlet water temperature;

Fig.27 is a diagram illustrating one example of the course of variation in temperature of water;

Fig.28 is a graph illustrating an output characteristic according to the engine inlet water temperature;

Fig.29 is a graph illustrating a torque characteristic according to the outlet/inlet water temperatures;

Fig.30 is a graph illustrating a knocking generation ignition timing characteristic based on the temperature of water; and

Figs.31A to 31C are diagrams illustrating variations in the opening degree of the variable flow rate control valve and in temperature of water in accordance with the variation in load.

Referring first to Fig.1 illustrating a first embodiment of the present invention, a cooling-water circulation circuit 1 is constructed to connect an engine body E with a radiator R. The cooling-water circulation circuit 1 comprises a passage 1a interconnecting an outlet in the engine body E and an inlet in the radiator R, and a passage 1b interconnecting an outlet in the radiator R and an inlet in the engine body E. The passages 1a and 1b are interconnected by a bypass circuit 2 bypassing the radiator R.

A flow rate control valve 3, continuously variable in opening degree, is disposed in the middle of the passage 1b in the cooling-water circulation circuit 1. The bypass circuit 2 is connected to the passage 1b downstream of the flow rate control valve 3, i.e. at a point closer to the engine body E. An electric-powered variable displacement water pump 4 is disposed in the passage 1b adjacent the engine body E.

Lines 6 and 7 each are connected at one end to the passage 1a in the cooling-water circulation circuit 1 through a switchover valve 5 and at their other end to the passage 1b between the flow rate control valve 3 and the water pump 4. A heater unit 8 is provided in the middle of the passage 6. A control valve 9 and a transmission oil heat exchanger 10 are provided in sequence from the upstream side in the middle of the other passage 7.

A radiator fan 11 mounted adjacent the radiator R is controlled in an on-off manner by a fan switch 12 which is disposed adjacent the outlet of the radiator R. When the temperature of the water in the outlet of the radiator R becomes equal to or higher than a predetermined value, the radiator fan 11 is operated.

The flow rate control valve 3, the water pump 4, the switchover valve 5, the control valve 9 and the fan 13 mounted to the heater unit 8 are controlled by a control means 14 comprising a computer. Connected to the control means 14 are an outlet water temperature detector 15 for detecting the engine outlet water temperature T_{WO} in the cooling-water circulation circuit 1 as an engine outlet water temperature, an inlet water temperature detector 16 for detecting the engine inlet water temperature T_{WI} in the cooling-water circulation circuit 1, a radiator water temperature detector 17 for detecting the radiator water temperature T_{WR} in the outlet of the radiator R, an oil temperature detector 18 for detecting the temperature T_O of a transmission oil, an open-air temperature detector 19 for detecting the temperature T_D of the open air, a compartment temperature detector 20 for detecting the temperature T_R within a compartment, a revolution number detector 21 for detecting the number of revolutions of the engine N_E (rate of engine revolutions) and an intake pressure detector 22 for detecting engine intake pressure P_B.

The control means 14 controls the operations of the flow rate control valve 3, the water pump 4, the switchover valve 5, the control valve 9 and the fan 13 in accordance with the above-described temperatures T_{WO}, T_{WI}, T_{WR}, T_O, T_D, and T_R, the engine revolution number N_E, as well as the engine intake pressure P_B. According to the present invention, the water pump 4 is controlled in accordance with at least the engine outlet water temperature T_{WO}, and the flow rate control valve 3 is controlled in accordance with at least the engine inlet water temperature T_{WI}. Control procedures established in the control means 14 for the control of the operations of the water pump 4 and the flow rate control valve 3 will be described below.

Fig.2 illustrates the control procedure established in the control means 14 to control the operation of the water pump 4 when the engine is in operation. At a first step S1, the engine rate of revolution number N_E, the engine intake pressure P_B and the engine outlet water temperature T_{WO} are read as parameters. At a second step S2, it is judged whether or not the engine outlet water temperature T_{WO} is equal to or greater than a reference water temperature T_{WS}, e.g., 80°C. If it is decided "no" at the second step S2, i.e. that $T_{WO} < T_{WS}$, the processing is advanced to a third step S3.

The motor for the water pump 4 is of an electric-powered type DC motor, and the displacement of the water pump 4 is varied by controlling the duty ratio of the motor. At the third step S3, the duty ratio D_O is searched from a map which has previously been established in accordance with the relationship between the engine outlet water temperature T_{WO} and the engine intake pressure P_B, as shown in Fig.3. More specifically, a plurality of duty ratios such as D_{01} (e.g. 5%), D_{02} (e.g. 10%), D_{03} (e.g. 20%), D_{04} (e.g. 30%), D_{05} (e.g. 40%) and the like have previously been established in accordance with the relationship of the valves of the engine outlet water temperature T_{WO} and the engine intake pressure P_B. When the engin outlet water temperature T_{WO} and the engine intake pressure P_B are low, the duty ratio D_O is set, for example, at about 5%. This value is an acceptabl

minimum value which insures a substantially uniform flow of the cooling water within the engine body E to produce no boiling within the engine body E.

Then, at a fourth step S4, the motor for the water pump 4 is operated on the basis of the searched duty ratio D_O. More specifically, the motor for the water pump 4 is controlled in an open loop by a fixed duty ratio determined in accordance with the engine outlet water temperature T_{WO} and the engine intake pressure P_B, when the engine outlet water temperature T_{WO} is lower than the reference water temperature T_{WS}.

If it is decided at the second step S2 that $T_{WO} \geqq T_{WS}$, a feed-back control is carried out according to fifth to tenth steps S5 to S10. At the fifth step S5, a target outlet water temperature T_{WOTR} is searched from a map which has previously been established in accordance with the engine revolution number N_E and the engine intake pressure P_B, as shown in Fig.4. In Fig.4, a target outlet water temperature $T_{WOTR}{}^1$ is set, for example, at 80 to 90°C, and a target outlet water temperature $T_{WOTR}{}^2$ is set, for example, at 130°C.

Then, a reference duty ratio D_{FS} which has previously been set in accordance with the relationship between the engine revolution number N_E and the engine intake pressure P_B as shown in Fig.5, is searched at a sixth step S6. As shown in Fig.5, five regions $D_{FS}{}^1$, $D_{FS}{}^2$, $D_{FS}{}^3$, $D_{FS}{}^4$ and $D_{FS}{}^5$ are established for the reference duty ratio D_{FS} in accordance with the relationship between the engine revolution number N_E and the engine intake pressure P_B. For example, $D_{FS}{}^1$ is 5%; $D_{FS}{}^2$ is 10%; $D_{FS}{}^3$ is 20 to 50%; $D_{FS}{}^4$ is 50 to 60%, and $D_{FS}{}^5$ is 80 to 100%.

At a seventh step S7, a difference ΔT_{WO} of water t mperature (= $T_{WO} - T_{WOTR}$) between the engine outl t water temperature T_{WO} and the target outlet water temperature T_{WOTR} is calculated. At a subsequent ighth step S8, a feed-back control value D_F is calculated as ($D_{FS} + K \cdot \Delta T_{WO}$), wherein K is a gain.

At a ninth step S9, it is judged whether or not the feed-back control value D_F obtained at the eighth step S8 is less than an acceptable minimum value D_{FMIN}. If $D_F < D_{FMIN}$, the feed-back control value D_F is increased to D_{FMIN} (i.e. $D_F = D_{FMIN}$) at a tenth step S10, and the processing is advanced to the fourth step S4. If $D_F \geqq D_{FMIN}$, then the processing is directly advanced to the fourth step S4 to bypass the tenth step S10.

Fig.6 illustrates the control procedure established for the control means 14 to control the operation of the flow rate control valve 3 in the operated condition of the engine. At a first step M1, the engine revolution number N_E, the engine intake pressure P_B, the engine inlet water temperature T_{WI} and the radiator water temperature T_{WR} are read as parameters. Then, at a second step M2, a target inlet water temperature T_{WITR} is searched from a map which has previously been established in accordance with the relationship between the engine revolution number N_E and the engine intake pressure P_B, as shown in Fig.7. In Fig.7, a target inlet water temperature $T_{WITR}1$ is 110°C, for example; a target inlet water temperature $T_{WITR}2$ is 80°C, for example, and a target inlet water temperature $T_{WITR}3$ is 60°C, for example.

At a third step S3, a gain K_{VC} in the feed-back control of the flow rate control valve 3 is calculated in the accordance with the engine inlet water temperature T_{WI} and the radiator water temperature T_{WR}. More specifically, the gain K_{VC} has previously been set, as shown in Fig.8, in accordance with a predetermined relationship of the difference ($T_{WR} - T_{WI}$) between the radiator water temperature T_{WR} and the engine inlet water temperature T_{WI}, and the gain K_{VC} is determined according to Fig.8.

At a fourth step M4, a feed-back control opening degree V_{CMD} of the flow rate control valve 3 is calculated. In other words, a calculation expression represented by $V_{CMD} = K_{VC} \cdot (T_{WI} - T_{WITR})$ is executed and at a next fifth step M5, the opening degree of the flow rate control valve 3 is controlled in accordance with the feed-back control opening degree V_{CMD}.

The operation of this embodiment now will be described. When the engine output water temperature T_{WO} does not reach the reference water temperature T_{WS} in an engine warming-up condition, the motor for the water pump 4 is controlled in the open loop on the basis of a fixed duty ratio D_O which is determined in accordance with the engine outlet water temperature T_{WO} and the engine intake pressure P_B. Moreover, when the engine outlet water temperature T_{WO} is in a low temperature condition equal to or lower than 20°C, the duty ratio D_0 is set at a value as low as 5%, permitting only a small amount of cooling water to flow through the engine body E. Thus, the temperature of the cooling water can be risen rapidly up to the reference water temperature T_{WS}, with the temperature uniformized at various portions of the engine body E. In this case, the flow rate control valve 3 is in its closed state, so that the cooling water is not passed through the radiator R, but is permitted to flow through the bypass circuit 2.

When the engine is in a low load condition, the target outlet water temperature T_{WOTR} in the feed-back control of the water pump 4 is set at a relatively high value, as high as 130°C, as shown in Fig.4, and the target inlet water temperature T_{WITR} in the feed-back control of the flow rate control value 3 is set at a relatively high value, as high as 110°C, as shown in Fig.7. This makes it possible to maintain the temperature of the cooling water in the engine body E at a relatively high level, and to provide a reduction in fuel consumption rate by a reduction in cooling loss and an improvement in atomization of the fuel. This avoids a deterioration of the nature of the exhaust gas.

Moreover, it is possible to control the amount of cooling water circulated by the water pump 4 to a minimum limit suitable for generating no boiling within the

engine body E. A section upstream of the water pump 4 cannot be brought into a depressurized state, irrespective of the opening degree of the flow rate control valve 3 and therefore, boiling cannot occur in the cooling water circulation circuit 1.

When the engine is brought into a high load condition, an optimal value of the cooling water temperature exists, as shown in Fig.9, for the purpose of providing a reduction in fuel consumption rate, and an optimal value of the cooling water temperature exists, as shown in Fig.10, for the purpose of avoiding the generation of engine knocking. From the viewpoints of a reduction in fuel consumption rate, the avoidance of the generation of knocking and an increase in engine output, the temperature of the cooling water in the engine body E can be controlled by controlling the displacement of the water pump 4 in accordance with the engine outlet water temperature T_{WO} and by controlling the opening degree of the flow rate control valve 3 in accordance with the engine inlet water temperature T_{WI}.

Because the gain K_{VC} in the feed-back control of the flow rate control valve 3 is varied in accordance with the radiator water temperature T_{WR} and the engine inlet water temperature T_{WI}, it is possible to control the ratio of the amount of cooling water flowing through the radiator R to the amount of cooling water flowing through the bypass circuit 2 to an optimal value to supply the cooling water having a temperature suitable for the load condition of the engine into the inlet of the engine body E.

A second embodiment of the present invention now will be described. In this embodiment, parts or components corresponding to those in the first embodiment are designated by like reference characters, and the detailed description thereof is omitted herein.

As shown in Fig.11, in addition to various detectors similar to those in the first embodiment, an atmospheric pressure detector 23 for detecting the atmospheric pressure P_A and a knocking detector 24 for detecting the knocking by the vibration of the engine body E are connected to the control means 14.

Fig.12 illustrates a main routine of a control procedure established in the control means 14 to control the operation of the water pump 4. When the engine is in operation, controls according to a subroutine in a normal mode and according to a subroutine in a knock judging mode are carried out, and when the operation of the engine is stopped, a control according to a subroutine in a post-stoppage mode is carried out. In the subroutine in the normal mode, the same control as the control of the operation of the water pump in the previous first embodiment is carried out (see Figs.2 to 5).

Fig.13 illustrates the subroutine in the knock judging mode. At a first step L1, it is judged whether or not a flag F is equal to "1". This flag F indicates whether or not the engine is in a knocking state. F = 1 indicates that the engine is in the knocking state, and F = 0 indicates that the engine is in a non-knocking state. If F = 0 at the first step L1, the processing is advanced to a second step L2. If F = 1 at the first step L1, the processing is advanced to a seventh step L7.

At the second step L2, it is judged on the basis of an output from the knocking detector 24 whether or not there is a knocking produced. When there is no knocking produced, the processing is advanced to a third step L3, at which a target outlet water temperature is searched from the map shown in Fig.4.

It it is decided at the second step L2 that there is the knocking produced, the flag F is set at "1" at a fourth step L4. Then, at a fifth step L5, a bias value D_{TW} of the target outlet water temperature is calculated according to a calculation expression, $D_{TW} = D_{TWO} = X_{D1}$, wherein D_{TWO} is, for example, 0°C, and X_{D1} is, for example, 5°C. At a sixth step L6, the target outlet water temperature T_{WOTR} is set at a value (T_{WOTR} = map value + D_{TW}) resulting from the addition of the bias value D_{TW} to the map value shown in Fig.4. In this case, D_{TW} is set at a negative value (e.g. -5°C) at the fifth step L5 and hence, at the sixth step L6, a value reduced from the map value in Fig.4 is set as the target outlet water temperature T_{WOTR}.

At the seventh step L7, it is judged on the basis of the output from the knocking detector 24 whether or not there is a knocking produced. If there is the knocking produced, the processing is advanced to an eighth step L8, at which a bias value D_{TW} of the target outlet water temperature is calculated according to a calculation expression, $D_{TW} = D_{TW} - X_D{}^2$), wherein $X_D{}^2$ is, for example, 3°C. At a next ninth step L9, the target outlet water temperature T_{WOTR} is set at a value (T_{WOTR} = map value + D_{TW}) resulting from addition of the bias value D_{TW} obtained at the eighth step L8 to the map value shown in Fig.4. In this case, D_{TW} is set at a negative value at the eighth step L8 and hence, at the ninth step L9, a value reduced from the map value in Fig.4 is set as the target outlet water temperature T_{WOTR}.

It it is decided at the seventh step L7 that there is no knocking produced, a bias value D_{TW} of the target outlet water temperature is calculated at a tenth step L10 according to a calculation expression, $D_{TW} = D_{TW} + X_P{}^3$, wherein $X_P{}^3$ is, for example, 1°C. At a next 11th step L11, the target outlet water temperature T_{WOTR} is set at a value (T_{WOTR} = map value + D_{TW}) resulting from addition of the bias value D_{TW} obtained at the tenth step L10 to the map value shown in Fig.4. In this case, the D_{TW} is determined by addition of, for example, 1°C by 1°C at the tenth step L10 and hence, the target outlet water temperature T_{WOTR} is gradually restored to the map value in Fig.4.

At a 12th step L12, it is judged whether or not the bias value D_{TW} is equal to or more than 0 (zero). If $D_{TW} \geqq 0$, the flag F is set at "0" at a 13th step L13.

With such a subroutine in the knock judging mode, when there is a knocking produced, the target outlet water temperature T_{WOTR} is reduced from the map value, for example, by 5°C at an initial stage of the knocking and thereafter, the target outlet water temperature T_{WOTR} is reduced from the map value with the decrement gradually increased by 3°C and by 3°C, until the knocking is eliminated. When the knocking has been eliminated, the target outlet water temperature T_{WOTR} is reduced from the map value with the decrement reduced by, for example, 1°C and by 1°C. When the decrement becomes "0", i.e. the target outlet water temperature T_{WOTR} is restored to the map value, the flag F is set "0", returning to the normal mode.

Fig.14 illustrates the subroutine in the post-stoppage mode of the engine. At a first step N1, the engine output water temperature T_{WO}, the atmospheric pressure P_A and the radiator water temperature T_{WR} are read as parameters. At a second step N2, an operative region is searched. That is, as shown in Fig.15, the operative region and an inoperative region according to the atmospheric pressure P_A and the engine output water temperature T_{WO} have previously been established with a hysteresis region (a region indicated by oblique lines in Fig.15) provided therebetween. At a third step N3, it is judged whether or not the engine is in the operative region in which the engine output water temperature T_{WO} is higher and the atmospheric pressure PA is lower (i.e. the vehicle is travelling at a higher elevation). If it is decided that the engine is in the inoperative region, the operation of the water pump 4 is stopped at a fourth step N4. On the other hand, if it is decided that the engine is in the operative region, the processing is advanced from the third step N3 to a fifth step N5.

At the fifth step N5, the duty ratio D_0' of the motor for the water pump 4 is searched from a map which has previously been established in accordance with the engine output water temperature T_{WO}, as shown in Fig. 16. The duty ratio D_0' is set so that it is continuously reduced with increase in engine output water temperature T_{WO}, when the operation of the engine is stopped. After stoppage of the engine, the control value in the open loop control of the water pump 4 is continuously varied in accordance with the engine output water temperature T_{WO}.

At a sixth step N6, the flow rate control valve 3 is forcibly opened, so that most of the cooling water that has been increased in temperature in the engine body E is permitted to flow through the radiator R.

At a seventh step N7, it is judged whether or not the radiator water temperature T_{WR} becomes equal to or higher than a preset water temperature T_{WRO}. This preset water temperature T_{WRO} is set higher than a temperature at which the radiator fan 11 mounted to the radiator R is operated by the fan switch 12. If $T_{WR} < T_{WRO}$, the processing is advanced to a ninth step N9. If $T_{WR} \geqq T_{WRO}$, the processing is advanced through an eighth step N8 to the ninth step N9.

At the eighth step N8, the cooling water is permitted to flow through the passage 6 having the heater unit 8 by the switchover valve 5 (see Fig.11), and the fan 13 applied to the heater unit 8. More specifically, when the radiator water temperature T_{WR} is not reduced even if the radiator fan 11 is operated, a portion of the cooling water is permitted to flow through the heater unit 8, so that releasing of a heat from the cooling water is promoted by the fan 13.

At the ninth step N9, the motor for the water pump 4 is controlled in the open loop by using the duty ratio D_0' obtained at the fifth step N5 as the control value.

The control procedure for controlling the flow rate control valve 3 in the engine-operated condition is the same as in the previously described first embodiment (see Figs.6 to 8).

With the construction of the second embodiment, in addition to the operation of the previously described first embodiment, the target value of the feed back control for the water pump 4, i.e. the target outlet water temperature T_{WOTR} is reduced when the knocking detector 24 has detected the knocking. Therefore, when the knocking is generated, a difference between the engine inlet temperature T_{WI} and the engine outlet water temperature T_{WO} is decreased. When this difference is decreased as shown in Fig.10, the knocking is difficult to generate, and hence, it is possible to promptly eliminate the knocking phenomenon after it has started to be generated, by reducing the target outlet water temperature T_{WOTR}.

In addition, since the operation of the water pump 4, after stoppage of the engine, is controlled in the open loop by use of the control value which is continuously varied in accordance with the engine outlet water temperature T_{WO}, it is possible to smoothly vary the amount of cooling water circulated as a result of cooling of the engine body E, to prevent the build-up of heat from being produced within the engine body E and to prevent the boiling of the cooling water and the failure of the starting of the engine at the restart thereof.

Although the opening degree of the flow rate control valve 3 has been controlled in accordance with the engine inlet water temperature T_{WI} in the above-described second embodiment, it is to be understood that a thermostat opened at a given temperature may be used. In this case, the sixth step N6 in the flow chart shown in Fig.14 is unnecessary.

Further, a third embodiment of the present invention now will be described. Referring first to Fig.17, a cooling water circulation circuit 1 is constructed to connect an engine E and a radiator R to each other. The cooling water circulation circuit 1 comprises a passage 1a interconnecting an outlet in the engine E

and an inlet in the radiator R, and a passage 1b interconnecting an outlet in the radiator R and an inlet in the engine E. The passages 1a and 1b are interconnected by a riser passage 36 which passes adjacent to and serves to control the temperature of a first idle valve 32 for automatically controlling the amount of air bypassing a throttle valve (not shown), an air control valve 33 for controlling the amount of air bypassing the throttle valve in response to a control signal, a throttle body 34 including a throttle valve, and a breather passage 35 together in series to bypass the radiator R.

An electromagnetic variable flow rate control valve 37, continuously variable in opening degree, is disposed in the passage 1a in the cooling water circulation circuit 1 at a location closer to the radiator R than the junction with the riser passage 36. A water pump 4_2 is disposed in the passage 1b in the cooling water circulation circuit 1 at a location closer to the engine E than riser passage 36 and is connected to a crank shaft (not shown) of the engine.

Passages 6 and 7 each are connected at one end thereof to the passage 1a in the cooling water circulation circuit 1 and at the other end thereof to the passage 1b in the cooling water circulation circuit 1 at a location closer to the radiator R than the water pump 4_2. A heater unit 8 is provided in the middle of the passage 6. A control valve 9 and a transmission oil heat exchanger 10 are provided in sequence from the upstream side in the middle of the other passage 7.

A radiator fan 11 adjacent the radiator R is controlled in an on-off manner by a fan switch 12 which is disposed adjacent the outlet of the radiator R. When the temperature of water in the outlet of the radiator R becomes equal to or higher than a predetermined value, the radiator fan 11 is operated.

The variable flow rate control valve 37 is controlled by a control means 14 comprising a computer. Connected to the control means 14 are an outlet water temperature detector 15 for detecting an engine outlet water temperature T_{WO} in the cooling water circulation circuit 1, an inlet water temperature detector 16 for detecting an engine inlet water temperature T_{WI} in the cooling water circulation circuit 1, a revolution number detector 21 for detecting the engine revolution number N_E, an intake pressure detector 22 for detecting the engine intake pressure P_B, and a knocking detector 24 for detecting the knocking by the vibration of the engine E.

The control means 14 controls the operation of the variable flow rate control valve 37 in accordance with the temperatures T_{WO} and T_{WI}, the engine revolution number N_E, the engine intake pressure P_B and an output from the knocking detector 24.

Figs.18 to 21 illustrate a flow chart for the control procedure established in the control means 14 to control the operation of the variable flow rate control valve 37. Referring first to Fig.18, at a first step P1, it is judged whether or not the engin E has been brought into a stabilized state after starting, by th fact whether or not th engine revolution number N_E has become a value exceeding a preset revolution number N_{ESTD}. If $N_E \leqq N_{ESTD}$, the processing is advanced to a second step P2 on the basis of the decision that the engine is in its started state. At the second step P2, a flag F is set at "1", progressing to a third step P3. On the other hand, if it has been confirmed at the first step P1 that $N_E > N_{ESTD}$, the processing is advanced to a third step P3 to bypass the second step P2.

At the third step P3, the engine revolution number N_E, the engine intake pressure P_B, the engine outlet water temperature T_{WO} and the engine inlet water temperature T_{WI} are read as parameters. At a next fourth step P4, it is judged whether or not the engine inlet water temperature T_{WI} exceeds a first preset temperature $T_{WIS}{}^1$ ($T_{WI} > T_{WIS}{}^1$). This first preset temperature $T_{WIS}{}^1$ is set, for example, at 60°C at which it can be decided that the warming-up of the engine is completed. If it is decided at the fourth step P4 that the $T_{WI} \leqq T_{WIS}{}^1$, the flag F is set at "1", progressing to a 13th step P13 (see Fig.19). On the other hand, if it is decided at the fourth step P4 that $T_{WI} > T_{WIS}{}^1$, the processing is advanced to a sixth step P6.

At the sixth step P6, it is judged whether or not the engine inlet water temperature T_{WI} is lower than a second preset temperature $T_{WIS}{}^2$ ($T_{WI} < T_{WIS}{}^2$). This second preset temperature $T_{WIS}{}^2$ is set, for example, at 90°C at which it can be decided that the engine is in an overheated state. If it is decided at the sixth step P6 that $T_{WI} < T_{WIS}{}^2$, the processing is advanced to a seventh step P7, at which the flag F is set at "0", progressing to a 22nd step P22 (see Fig.20). On the other hand, if it is decided at the sixth step P6 that $T_{WI} < T_{WIS}{}^2$ the processing is advanced to an eighth step P8.

At the eighth step P8, it is judged whether or not the flag F is at "1". If F = 1, the processing is advanced to a ninth step P9. If F = 0, the processing is advanced to a tenth step P10.

At the ninth step P9, the flag F is searched according to a first map shown in Fig.22, and the flag F is reset on the basis of the result of such search. At the tenth step P10, the flag F is searched from a second map shown in Fig.23, and the flag F is reset on the basis of the result of such search. Both the first and second maps are defined to provide a region of the flag F equal to "0" and a region of the flag F equal to "1" on the basis of the engine revolution number N_E and the engine intake pressure P_B. In the first map, a boundary line A_1 dividing the first map into the region of F = 0 and the region of F = 1 is established at a level of the intake pressure P_B higher than that of a boundary line A_2 dividing the second map into the region of F = 0 and the region of F = 1. That is, a hysteresis is established in rewriting the flag F on the ba-

sis of the engine revolution number N_E and the engine intake pressure P_B.

After completion of the processing at the ninth and tenth steps P9 and P10, it is judged whether or not the flag is at "1" at an 11th step P11. If F=1, the processing is advanced to a 13th step P13. If F=0, the processing is advanced to a 12th step P12.

At the 12th step P12, it is judged whether or not a predetermined time T_{STD} has lapsed from a time point when the flag has become "0". If the predetermined time T_{STD} has still not lapsed, the processing is advanced to a 13th step P13. If the predetermined time T_{STD} has been lapsed, the processing is advanced to a 22th step P22.

Referring to Fig.19, at the 13th step P13, a target outlet temperature T_{WO}^0 is searched from a map which has been established on the basis of the engine revolution number N_E and the engine intake pressure P_B. If it is decided at a 14th step P14 that the engine outlet water temperature T_{WO} is lower than the target outlet temperature T_{WO}^0 ($T_{WO} < T_{WO}^0$), the opening degree of the variable flow rate control valve 37 is determined to need to be at a full closed level at a 15th step P15, and the variable flow rate control valve 37 is oprated at a 16th step P16.

If it is decided at the 14th step P14 that $T_{WO} \geqq T_{WO}^0$, the feedback control is carried out at 17th to 21st steps P17 to P21. First, at the 17th step P17, a reference duty ratio D_{BO} is searched from a map which has previously been established in correspondence to the target outlet temperature T_{WO}^0. More specifically, the opening degree of the variable flow rate control valve 37 of the electromagnetic type is varied by controlling the duty ratio of energization of a solenoid. At the 17th step P17, the duty ratio D_{BO} as a criterion is provided. A difference ΔT_{WO} (= $T_{WO} - T_{WO}^0$) between the engine outlet water temperature T_{WO} and the target outlet temperature T_{WO}^0 is calculated at a 18th step P18. A feed-back control value D_F is calculated as ($D_{BO} + K \bullet \Delta T_{WO}$) at a 19th step P19, wherein K is a gain.

At a 20th step P20, it is judged whether or not the feed-back control value D_F obtained at the 19th step P19 is less than an acceptable minimum value D_{FM}^1. If $D_F < D_{FM}^1$, the feed-back control value D_F is increased to become equal to an acceptable minimum value D_{FM}^1 (i.e., $D_F = D_{FM}^1$ is established) at a 21st step P21, progressing to the-16th step P16. On the other hand, if $D_F \geqq D_{FM}^1$, the processing is advanced to the 16th step P16 to bypass the 21st step P21.

At a 22nd step P22 in Fig.20, a target inlet temperature T_{WIO} is searched from a map which has previously been established on the basis of the engine revolution number N_E and the engine intake pressure P_B. At a 23rd step, it is judged whether or not there is a knocking phenomenon produced, i.e. whether or not there is no knocking detected by the knocking detector 23. If it is decided that there is the knocking produced, the processing is advanced to a 29th step P29 (see Fig.21). If it is decided that there is no knocking produced, the processing is advanced to a 24th step P24.

At the 24th to 28th steps P24 to P28, the feedback control according to the target inlet temperature T_{WIO} is carried out. At the 24th step P24, a reference duty ratio D_{BI} is searched from a map which has previously been established in correspondence to the target inlet temperature T_{WIO}. A difference ΔT_{WI} (= $T_{WI} - T_{WI}^0$) between the engine inlet water temperature T_{WI} and the target inlet temperature T_{WI}^0 is calculated at a 25th step P25. A feed-back control value D_F is calculated as ($D_B^1 + K \bullet \Delta T_W^1$) at a 26th step P19, wherein K is a gain.

At a 27th step P27, it is judged whether or not the feed-back control value D_F obtained at the 26th step P26 is less than an acceptable minimum value D_{FM}^2. If $D_F < D_{FM}^2$, then $D_F = D_{FM}^2$ is established at a 28th step P28, progressing to the 16th step P16 (see Fig.19). If $D_F \geqq D_{FM}^2$ in step P27, the processing is advanced to the 16th step P16 to bypass the 28th step P28.

Fig.21 illustrates the control procedure carried out at 29th to 39th steps P29 to P39, when there is a knocking produced. At the 29th step P29, the target inlet temperature T_{WIO} is decreased by a given value (e.g. 3°C), and at a 30th step P30, a reference duty ratio D_{BI}, is searched on the basis of the decreased target inlet temperature T_{WIO}. Then, a difference ΔT_{WI} (= $T_{WI} - T_{WIO}$) between the engine inlet water temperature T_{WI} and the target inlet temperature T_{WIO} is calculated at a 31st step P31, and it is judged at a 32nd step whether or not the difference ΔT_{WI} is positive ($\Delta T_{WI} > 0$). If $\Delta T_{WI} \leqq 0$, $\Delta T_{WI} = 0$ is established at a 33rd step P33, progressing to a 34th step P34. If $\Delta T_{WI} > 0$ the processing is advanced to a 34th step P34 to bypass the 33rd step P33.

At the 34th step P34, a difference ΔT_W (= $T_{WO} - T_{WI}$) between the engine outlet water temperature T_{WO} and the engine inlet water temperature T_{WI} is calculated. Then, it is judged at a next 35th step whether or not the temperature difference ΔT_W exceeds a given value. If it is decided that $\Delta T_W \leqq$ the given value, the temperature difference ΔT_W is increased to become equal to the given value (ΔT_W = the given value) at a 36th step P36, then progressing to a 37th step P37. If it is decided that $\Delta T_W >$ the given value, the processing is advanced to a 37th step to bypass the 36th step P36.

At the 37th step, a feed-back control value D_F is calculated as ($D_{BI} + K \bullet \Delta T_{WI} + K' \bullet \Delta T_W$), wherein K' is a gain.

At a 38th step, it is judged whether or not the feed-back control value D_F obtained at the 37th step P37 is less than an acceptable minimum value D_{FM}^2. If $D_F < D_{FM}^2$ the relation , $D_F = D_{FM}^2$, is established in a 39th step P39, the progressing to the 16th step P16

(see Fig.19). If $D_F \geqq D_{FM}^2$, the processing is advanced to the 16th step to bypass the 39th step.

Such control procedure now will be summarized. After starting of the engine, in a lower water temperature region in which the inlet water temperature T_{WI} is equal to or lower than the first preset temperature T_{WIS}^1 (e.g. 60°C), the control using, as a target value, a target outlet temperature T_{WO}^0 determined by the engine revolution number N_E and the engine intake pressure P_B is carried out according to the procedure for the 13th to 21st steps P13 to P21. More specifically, when the engine outlet water temperature T_{WO} is lower than the target outlet temperature T_{WO}^0 determined by the engine revolution number N_E and the engine intake pressure P_B, the variable flow rate control valve 37 is brought into its fully closed state. When the engine outlet water temperature T_{WO} becomes equal to or higher than the target outlet temperature T_{WO}^0, the opening degree of the variable flow rate control valve 37 is determined by the feed-back control using the target outlet temperature T_{WO}^0 as the target value.

In a condition in which there is no knocking phenomenon produced in a higher water temperature region in which the engine inlet water temperature T_{WI} is equal to or higher than the second preset temperature T_{WIS}^2 (e.g., 90°C), the feed-back control using a target outlet temperature T_{WI}^0 determined by the engine revolution number N_E and the engine intake pressure P_B as a target value is carried out according to the procedure for the 22nd to 28th steps P22 to P28.

Further, a mean water temperature region is established in which the engine inlet water temperature T_{WI} exceeds the first preset temperature T_{WIS}^1 and is lower than the second preset temperature T_{WIS}^2. In this mean water temperature region, a control using a target outlet temperature T_{WO}^0 as a target value is carried out in a low load condition according to the procedure for the 13th to 21st steps P13 to P21. In a high load condition and when there is no knocking produced, a feed back control using a target inlet temperature T_{WIO} determined by the engine revolution number N_E and the engine intake pressure P_B as a target value is carried out according to the procedure for the 22nd to 28th steps P22 to P28. If a knocking is produced during the feed-back control using the target inlet temperature T_{WI}^0 as the target value, a feed back control of the variable flow rate control valve 37 is carried out according to the procedure for the 29th to 39th steps P29 to P39, so that the target inlet temperature T_{WIO} reduced by the given value is brought into the target value, and the temperature difference ΔT_W between the engine outlet temperature ΔT_{WO} and the engine inlet temperature T_{WI} is decreased.

Moreover, in the mean water temperature region, a hysteresis is established when the lower and higher load conditions ar switched over from one to another, but also, when the lower load condition is switched over to the higher load condition, the control using the target inlet temperature T_{WIO} as the target value can be started only after a lapse of a given time T_{STD} from the time point when the higher load condition is reached.

The operation of the third embodiment now will be described. In the engine warming-up course in which the engine inlet water temperature T_{WI} is lower than the first preset temperature T_{WIS}^1, the opening degree of the variable flow rate control valve 37 is controlled by use of the target outlet temperature T_{WO}^0 as the target value. The variable flow rate control valve 37 is in its closed state, until the engine outlet water temperature T_{WO} reaches the target outlet temperature T_{WO}^0. In this case, the cooling water is permitted to flow through the riser passage 36, but the amount of water discharged from the water pump 4_2 is extremely small, because of a relative large resistance to the flowing through the riser passage 36. Thus, the amount of water flowing through the engine E is extremely small, thereby providing an early increase in the temperature of the engine oil, the shortening of the warming-up time and reductions in cooling loss and in friction loss.

When the engine outlet water temperature T_{WO} is increased to a certain extent, the increase in the temperature of the oil in the transmission can be provided by opening the control valve 9, thereby further reducing the friction loss. The amount of water introduced from the radiator R is increased by gradually increasing the opening degree of the variable flow rate control valve 37.

In this case, the setting of the target outlet temperature T_{WO}^0 at a relatively high value, e.g. 110°C ensures that the net fuel consumption rate and the indicated specific fuel consumption rate can be reduced with the reduction in cooling loss, as shown in Figs.24 and 25, and the friction loss can be reduced, as shown in Fig.26. In addition, the unburned hydrocarbon in the exhaust gas can be reduced to improve the nature of the exhaust gas.

After the engine outlet temperature T_{WO} once exceeds the target outlet temperature T_{WO}^0, the minimum opening degree of the variable flow rate control valve 37 is maintained, so that the amount of water flowing through the engine E cannot be substantially varied, and the temperature of the water is stably varied with time, as shown by a solid line in Fig.27, thereby enabling a stable operation of the engine. In contrast, when the minimum opening degree of the variable flow rate control valve 37 is not defined, the temperature of the water is substantially varied, as shown by a dashed lines in Fig.27 and as a result, it is difficult to stably operate the engine.

The mean water temperatur region in which the engine inlet temperature T_{WI} exceeds the first preset temperature T_{WIS}^1 and is lower than the second pre-

set temperature T_{WIS}^2 is established after completion of the warming-up of the engine. In this mean water temperature region, the state for controlling the opening degree of the variable flow rate control valve 37 to bring the engine outlet water temperature T_{WO} into the target outlet temperature T_{WO}^0 during the operation of the engine at a low load and the state for controlling the opening degree of the variable flow rate control valve 37 to bring the engine inlet water temperature T_{WI} into the target inlet temperature T_{TWIO} during the operation of the engine at a high load are switched over from one to another. This makes it possible to achieve a reduction in fuel consumption rate and to provide a good nature of exhaust gas during the low load operation of the engine in the same manner as in the above-described warming-up of the engine. On the other hand, during the high load operation of the engine, an increase in output can be achieved by providing the control on the basis of the target inlet temperature T_{WIO} determined in accordance with the engine revolution number N_E and the load. More specifically, during the operation of the engine at a high engine revolution number and a high load, the increase in output can be achieved, as shown in Fig.28, by previously setting the target inlet temperature T_{WIO}, for example, at 80 to 90°C. During the operation of the engine at low to medium engine revolution numbers and a high load, the increase in output torque can be achieved, as shown in Fig.29, by previously setting the target inlet temperature T_{WIO}, for xample, at 60°C. Thus, a more precise control can be carried out in accordance with the operational condition of the engine.

It is known that when the engine is brought into the condition of high load operation, the engine knocking is difficult to generate, if the engine inlet water temperature T_{WI} is lower and the difference ΔT_W between the engine outlet water temperature T_{WO} and the engine inlet water temperature T_{WI} is smaller, as shown in Fig.30. When the knocking is detected by the knocking detector 24, the opening degree of the variable flow rate control valve 37 is controlled, so that the target inlet temperature T_{WIO} is reduced, and the difference ΔT_W between the engine outlet water temperature T_{WO} and the engine inlet water temperature T_{WI} is decreased, and as a result, the knocking is difficult to generate. Therefore, it is possible to promptly eliminate the knocking phenomenon once it has been generated, without provision of a retard of ignition timing and a richening of a fuel-air mixture.

Further, in the mean water temperature region, when the engine load is varied as shown in Fig.31A, the opening degree of the variable flow rate control valve 37 is varied as shown in Fig.31B. In accordance with this, the temperature of water is varied as shown in Fig.31C. When the engine load is changed from a low level to a high level, a problem of an overchute or the like as shown in Fig.31C cannot occur. When the engine load is changed from the high level to the low level, the opening degree of the variable flow rate control valve 37 is varied with a delay toward the closed side, and a sudden underchute cannot be produced, because of the hysteresis established. However, if the control of the variable flow rate control valve 37 is immediately changed to the control using the target inlet temperature T_{WIO} as the target value in response to the changing of the engine load from the low load to the high load, when the control using the target outlet temperature T_{WO}^0 as the target value is being carried out during the operation of the engine at the low load in the mean water temperature region, a lot of time is taken until cooling water having a low temperature is introduced into the engine E and returned. Thereupon, it is judged at the 12th step P12 in Fig.18 whether or not the predetermined time has lapsed from the time point when the engine load has been changed from the low load to the high load. Until the predetermined time has lapsed, the control using the target inlet temperature T_{WIO} as the target value is not started. This causes the temperature of the engine E to be increased slightly, but the above-described problem of the time can be accommodated by previously establishing the first map shown in Fig.22 as well as the second map shown in Fig.23, so that such increase in the temperature of the engine E is acceptable.

Moreover, in this cooling system, the variable flow rate control valve 37 is mounted in the middle of the passage 1a interconnecting the outlet of the engine E and the radiator R to constitute a portion of the cooling water circulation circuit 1 and therefore, a bypass passage conventionally provided to bypass the radiator R can be eliminated, thereby reducing the amount of water carried in the cooling water circulation circuit 1 to provide an improvement in warming-up property and a reduction in weight.

Although the several embodiments of the present invention have been described in detail, it will be understood that the present invention is not intended to be limited to these embodiments, and various minor modifications in design can be made without departing from the scope of the invention defined in the claims.

For example, the riser passage 36 in the third embodiment can be omitted. In this case, the 14th and 15th steps P14 and P15 in the flow chart in Fig.19 are unnecessary, and the processing is advanced from the 13th step P13 to the 17th step P17.

Claims

1. An engine cooling system comprising
   a cooling water circulation circuit interconnecting an engine body and a radiator,
   a bypass circuit connected to the cooling

water circulation circuit to bypass the radiator,

an electric-powered variable displacement water pump disposed in the cooling water circulating circuit adjacent an engine inlet,

a flow rate control valve for controlling the flow rate of cooling water flowing through the radiator,

an outlet water temperature detector for detecting an engine outlet water temperature in the cooling water circulation circuit,

an inlet water temperature detector for detecting an engine inlet water temperature in the cooling water circulation circuit, and

a control means for controlling the operation of the water pump in accordance with at least the engine outlet water temperature and controlling the operation of the flow rate control valve in accordance with at least the engine inlet water temperature.

2. An engine cooling system according to claim 1, wherein said control means controls the water pump and the flow rate control valve in accordance with the engine outlet and inlet water temperatures and an operational condition of the engine, other than said water temperatures, including at least the engine revolution number.

3. An engine cooling system according to claim 1 or 2, wherein said control means is capable of performing a feed-back control of the water pump operation using, as a target value, a target outlet water temperature determined from at least the engine revolution number and the engine intake pressure as parameters, and performing a feedback control of the flow rate control valve using, as a target value, a target inlet water temperature determined from at least the engine revolution number and the engine intake pressure as parameters.

4. An engine cooling system according to claim 3, wherein said control means is capable of being switched over between a state for performing the feed-back control of the water pump, when the engine outlet water temperature is equal to or higher than a reference water temperature, and an open loop control of the water pump using a control value based on the engine outlet water temperature and the engine intake pressure, when the engine outlet water temperature is lower than said reference water temperature.

5. An engine cooling system according to claim 3 or 4, wherein said control means varies the gain in the feedback control of the flow rate control valve in accordance with the temperature of water in the radiator and the engine inlet water temperatur .

6. An engine cooling system comprising

a cooling water circulation circuit interconnecting an engine body and a radiator,

an electric-powered variable displacement water pump disposed in the cooling water circulation circuit adjacent an engine inlet,

a water temperature detector for detecting an engine water temperature, and

a control means for controlling the operation of the water pump in such a manner to switch-over a feed-back control according to the engine water temperature and an open loop control from one to another in accordance with the operational condition of an engine.

7. An engine cooling system according to claim 6, wherein said control means is capable of being switched over between a state for performing the feed-back control, when the engine water temperature is equal to or higher than a predetermined reference water temperature, and a state for performing the open loop control, when the engine water temperature is lower than said predetermined reference water temperature.

8. An engine cooling system according to claim 7, wherein said control means has a control value previously set therein in correspondence to an acceptable minimum displacement of the water pump, which insures a substantially uniform flowing of cooling water within the engine body in conducting the open loop control, when the engine water temperature is lower than said reference water temperature.

9. An engine cooling system according to claim 6, 7 or 8, wherein said control means performs the open loop control of the water pump using the control value continuously varied in accordance with the engine water temperature, when the operation of the engine is stopped.

10. An engine cooling system comprising

a cooling water circulation circuit interconnecting an engine body and a radiator,

an electric-powered variable displacement water pump disposed in said cooling water circulation circuit adjacent an engine inlet,

an engine outlet water temperature detector for detecting an engine outlet water temperature,

a knocking detector for detecting the knocking of the engine, and

a control means capable of performing a feed-back control of the water pump in accordance with the engine outlet water temperature

and reducing a target value for the feed-back control, when knocking is detected.

11. An engine cooling system comprising
a cooling water circulation circuit interconnecting an engine body and a radiator,
a variable flow rate control valve mounted in said cooling water circulation circuit,
an engine inlet water temperature detector for detecting an engine inlet water temperature,
an engine outlet water temperature detector for detecting an engine outlet water temperature, and
a control means capable of being switched over between a state for controlling the opening degree of the variable flow rate control valve to bring the engine outlet water temperature into a target outlet temperature, when the engine inlet water temperature is in a low water temperature region, and a state for controlling the opening degree of the variable flow rate control valve to bring the engine inlet water temperature into a target inlet temperature, when the engine inlet water temperature is in a high water temperature region.

12. An engine cooling system according to claim 11, wherein a mean water temperature region is established between the low and high water temperature regions, and said control means is capable of being switched over between a state for controlling the opening degree of the variable flow rate control valve to bring the engine outlet water temperature into the target outlet temperature during the operation of the engine at a low load in a condition in which the engine inlet water temperature is in said mean water temperature region, and a state for controlling the opening degree of the variable flow rate control valve to bring the engine inlet water temperature into a target inlet temperature during the operation of the engine at a high load in a condition in which the engine inlet water temperature is in said mean water temperature region.

13. An engine cooling system according to claim 12, further including a knocking detector connected to said control means for detecting the knocking of the engine, and wherein said control means controls the opening degree of the variable flow rate control valve so as to reduce the target inlet temperature and reduce the difference between the engine outlet water temperature and the engine inlet water temperature in response to the detection of the knocking during the operation of the engine at a high load in the mean water temperature region.

14. An engine cooling system according to claim 11,12 or 13, wherein said variabl flow rate control valve is mounted in the middle of a passage interconnecting an engine outlet and the radiator to constitute a portion of said cooling water circulation circuit.

15. An engine cooling system comprising
a cooling water circulation circuit interconnecting an engine body and a radiator,
means circulating cooling water in the cooling water circulation circuit
an outlet water temperature detector for detecting an engine outlet water temperature in the cooling water circulation circuit,
an inlet water temperature detector for detecting an engine inlet water temperature in the cooling water circulation circuit, and
a control means for controlling the circulation of the cooling water through the engine body in response to both said detected temperatures for minimizing the temperature difference between said engine outlet water temperature and said engine inlet water temperature for minimizing engine knocking.

16. An engine cooling system according to claim 15, wherein said circulating means includes a water pump and flow rate control valve for controlling the rate of flow of cooling water through the radiator.

17. An engine cooling system according to claim 16, wherein said water pump includes means for selectively varying the rate of flow of cooling water.

18. An engine cooling system according to claim 17, wherein said control means controls the water pump and the flow rate control valve in accordance with the engine outlet and inlet water temperatures and an operational condition of the engine, including at least the engine revolution number, other than said water temperatures.

FIG.1

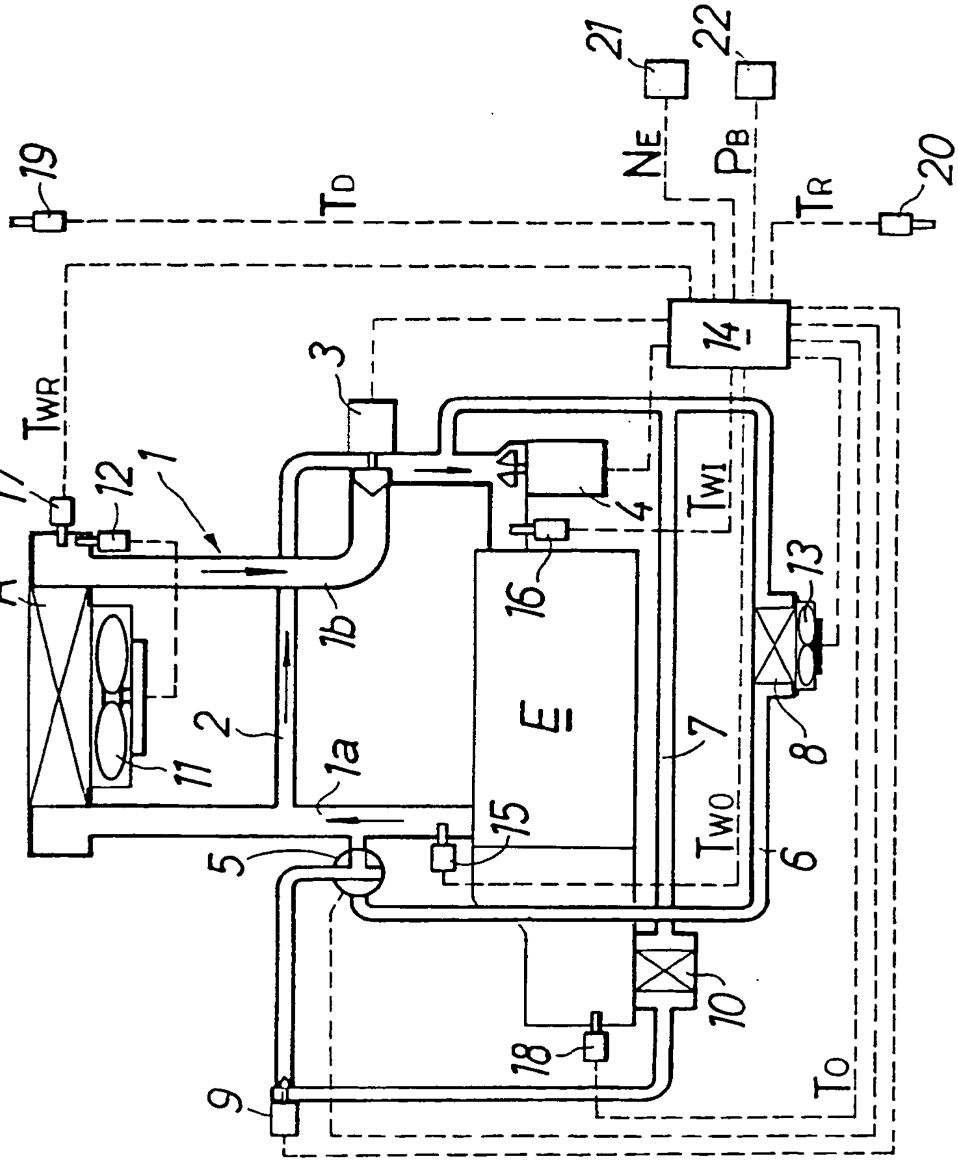

R
17
12
1
T_{WR}
3
19
T_D
21
22
N_E
P_B
T_R
20
14
4
T_{WI}
16
13
1b
2
1a
11
E
7
8
5
15
T_{WO}
6
10
18
9
T_O

FIG. 2

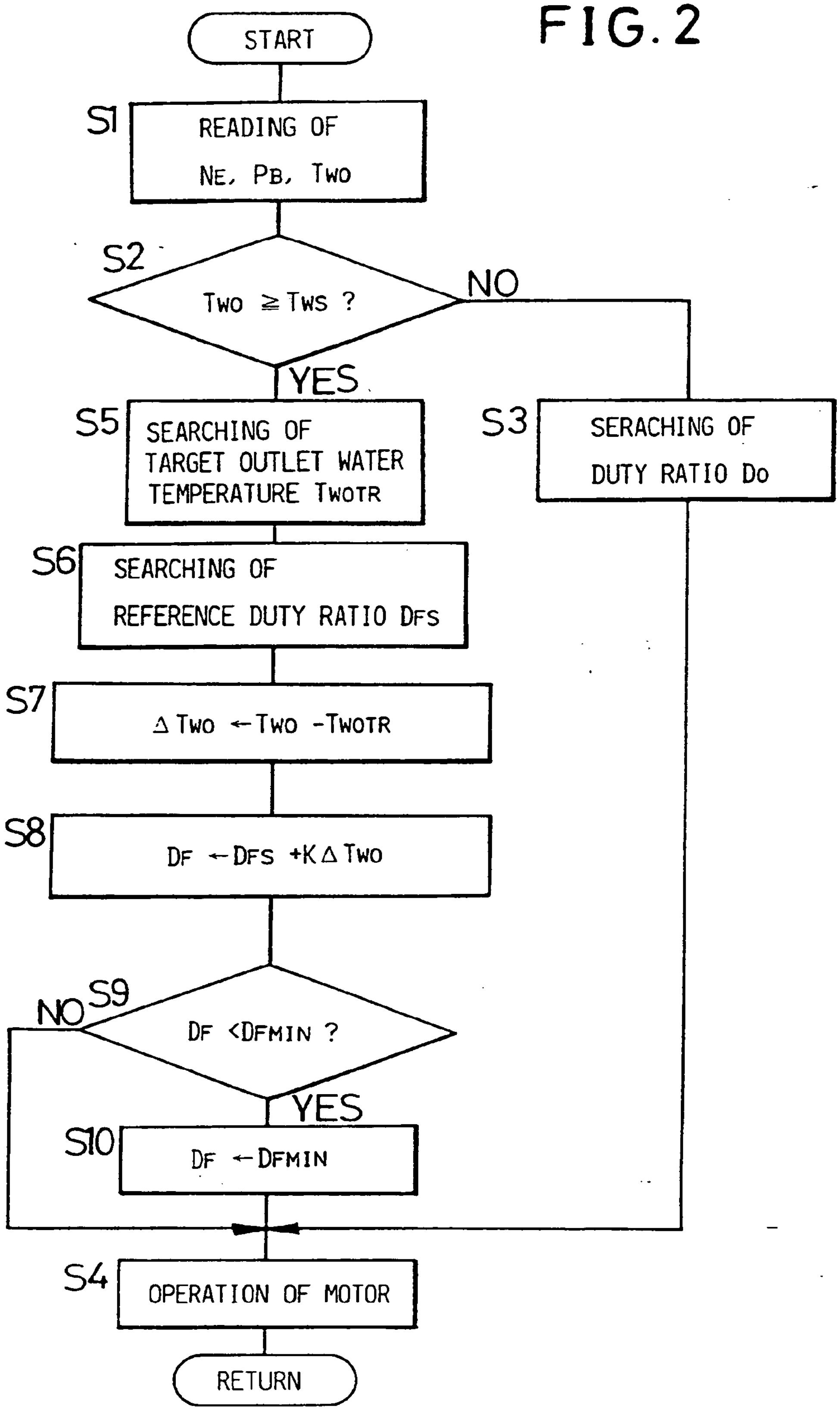

START
S1
READING OF
NE, PB, TWO
S2
TWO ≧ TWS ?
NO
YES
S5
SEARCHING OF
TARGET OUTLET WATER
TEMPERATURE TWOTR
S3
SERACHING OF
DUTY RATIO Do
S6
SEARCHING OF
REFERENCE DUTY RATIO DFS
S7
ΔTWO ← TWO - TWOTR
S8
DF ← DFS + KΔTWO
S9
NO
DF < DFMIN ?
YES
S10
DF ← DFMIN
S4
OPERATION OF MOTOR
RETURN

FIG.3

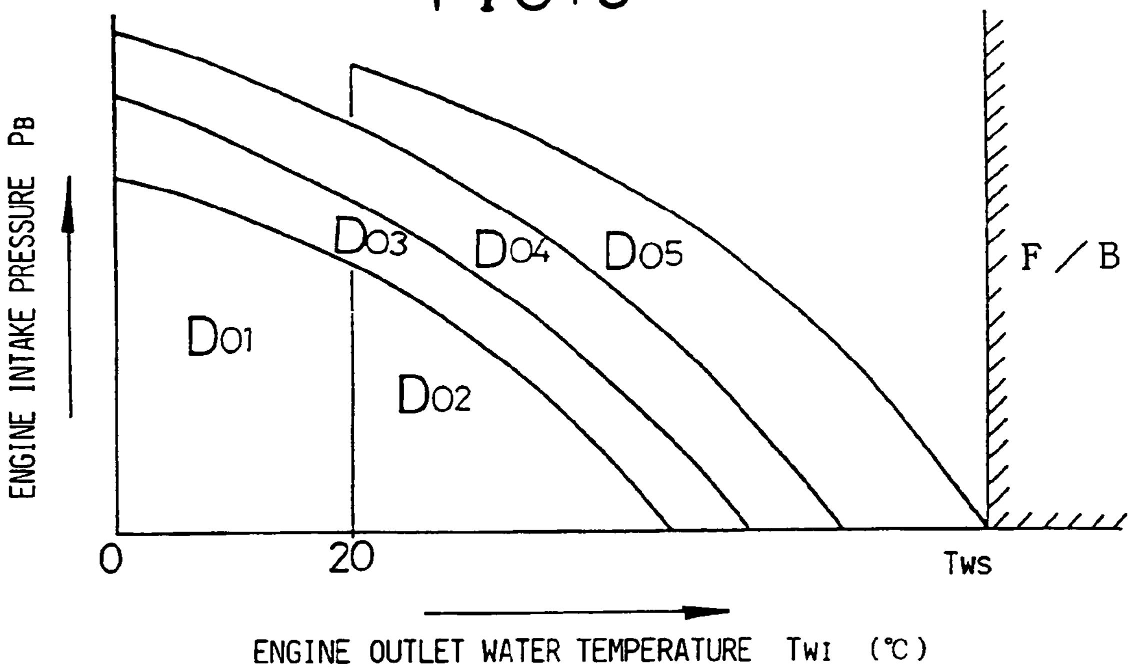

ENGINE INTAKE PRESSURE PB
DO1
DO2
DO3
DO4
DO5
F / B
0
20
TWS
ENGINE OUTLET WATER TEMPERATURE TWI (℃)

FIG.4

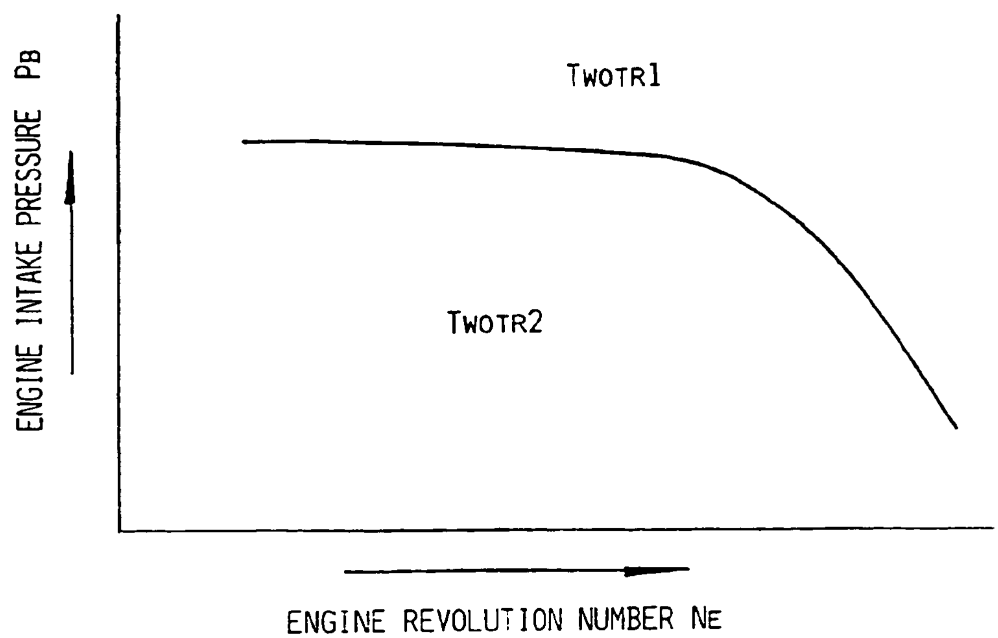

ENGINE INTAKE PRESSURE PB
TWOTR1
TWOTR2
ENGINE REVOLUTION NUMBER NE

FIG. 5

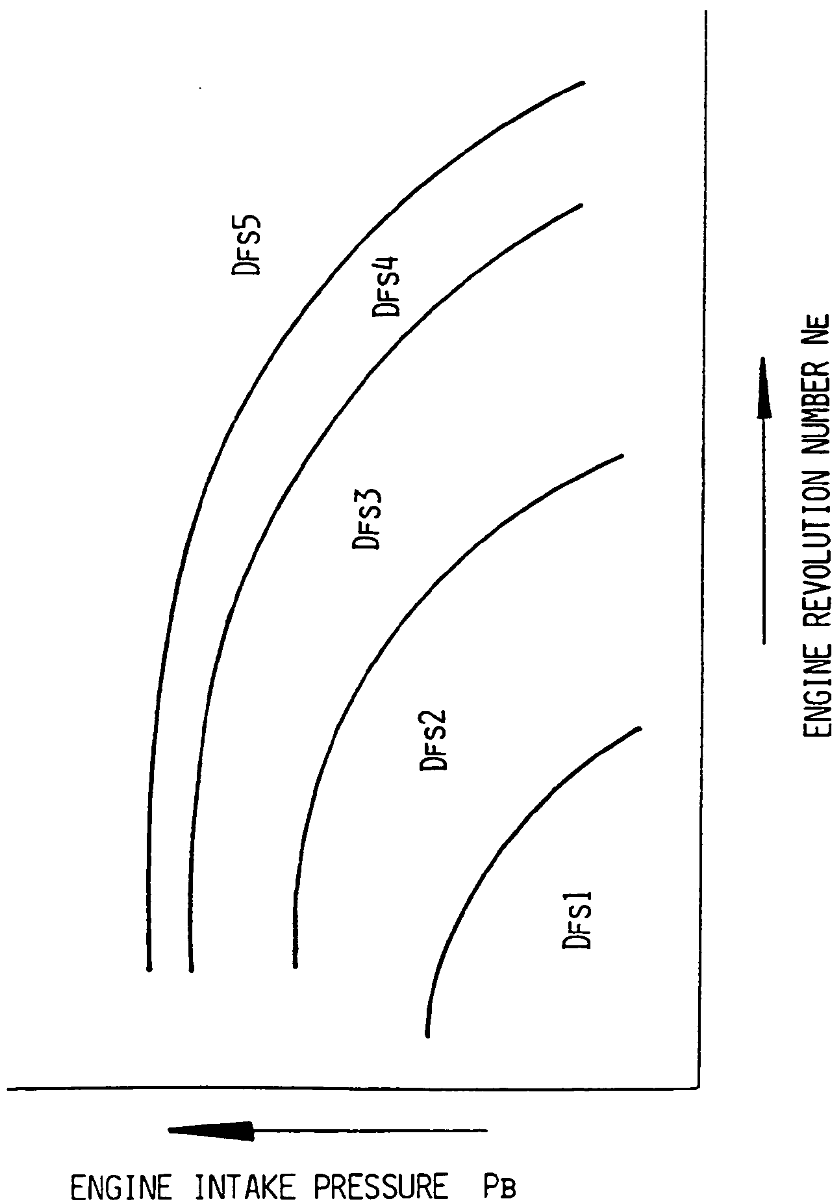

DFS5
DFS4
DFS3
DFS2
DFS1
ENGINE REVOLUTION NUMBER NE
ENGINE INTAKE PRESSURE PB

FIG.6

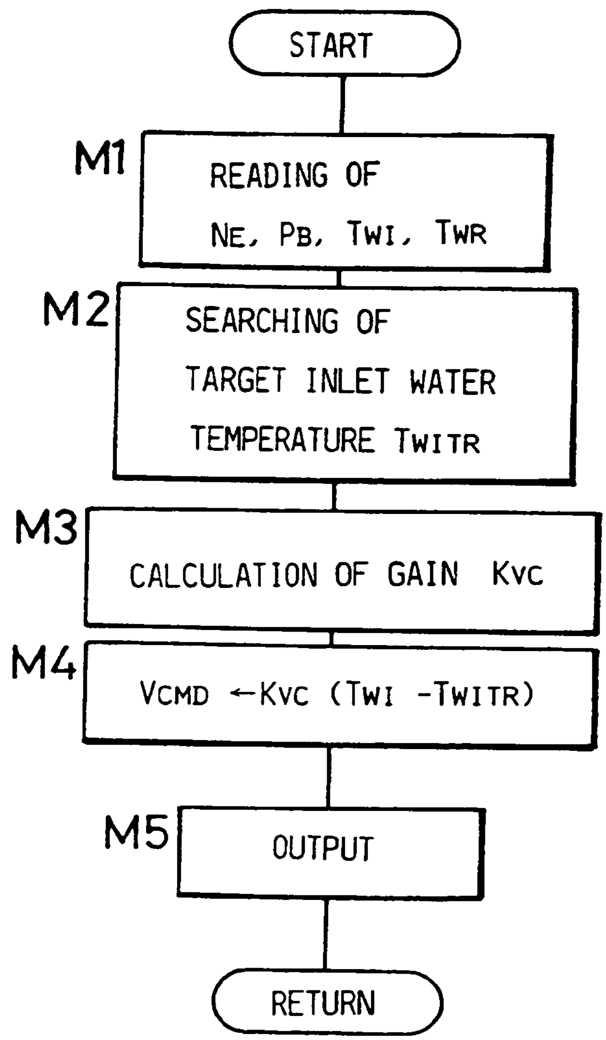

START
M1
READING OF
NE, PB, TWI, TWR
M2
SEARCHING OF
TARGET INLET WATER
TEMPERATURE TWITR
M3
CALCULATION OF GAIN KVC
M4
VCMD ←KVC (TWI -TWITR)
M5
OUTPUT
RETURN

FIG.7

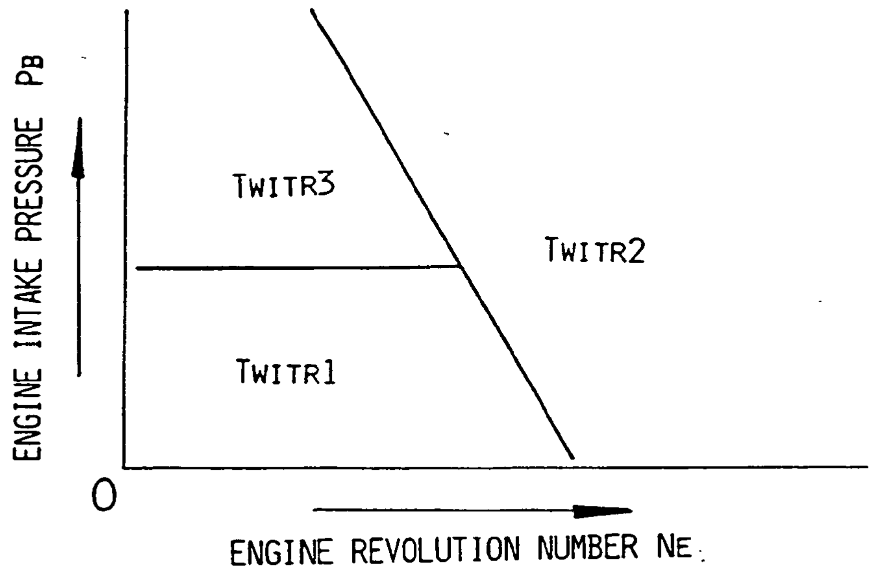

ENGINE INTAKE PRESSURE PB
TWITR3
TWITR2
TWITR1
0
ENGINE REVOLUTION NUMBER NE

FIG.8

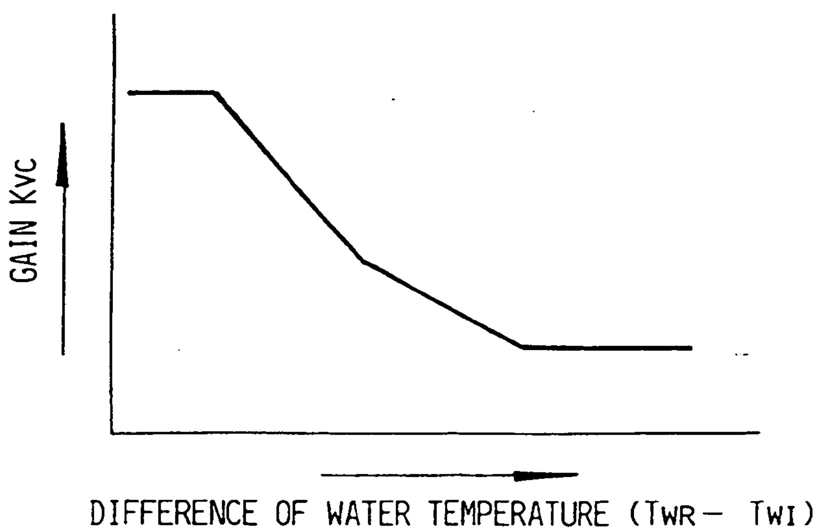
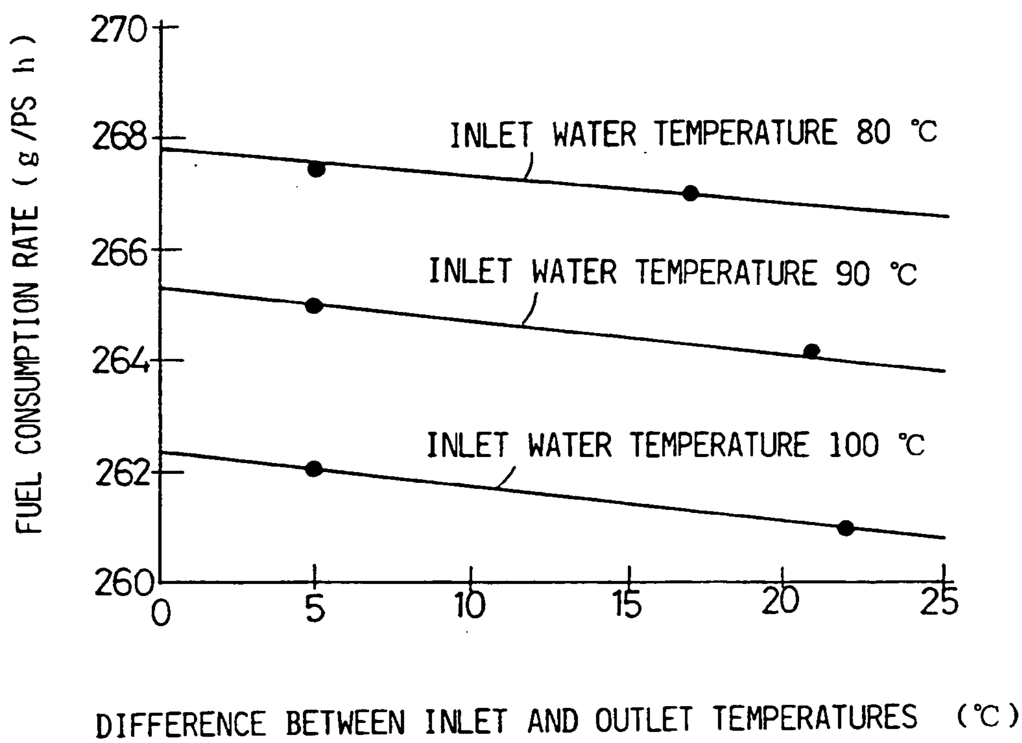

GAIN KVC
DIFFERENCE OF WATER TEMPERATURE (TWR− TWI)

FIG.9



270
268
266
264
262
260
0
5
10
15
20
25
FUEL CONSUMPTION RATE (g /PS h)
INLET WATER TEMPERATURE 80 ℃
INLET WATER TEMPERATURE 90 ℃
INLET WATER TEMPERATURE 100 ℃
DIFFERENCE BETWEEN INLET AND OUTLET TEMPERATURES (℃)

FIG.10

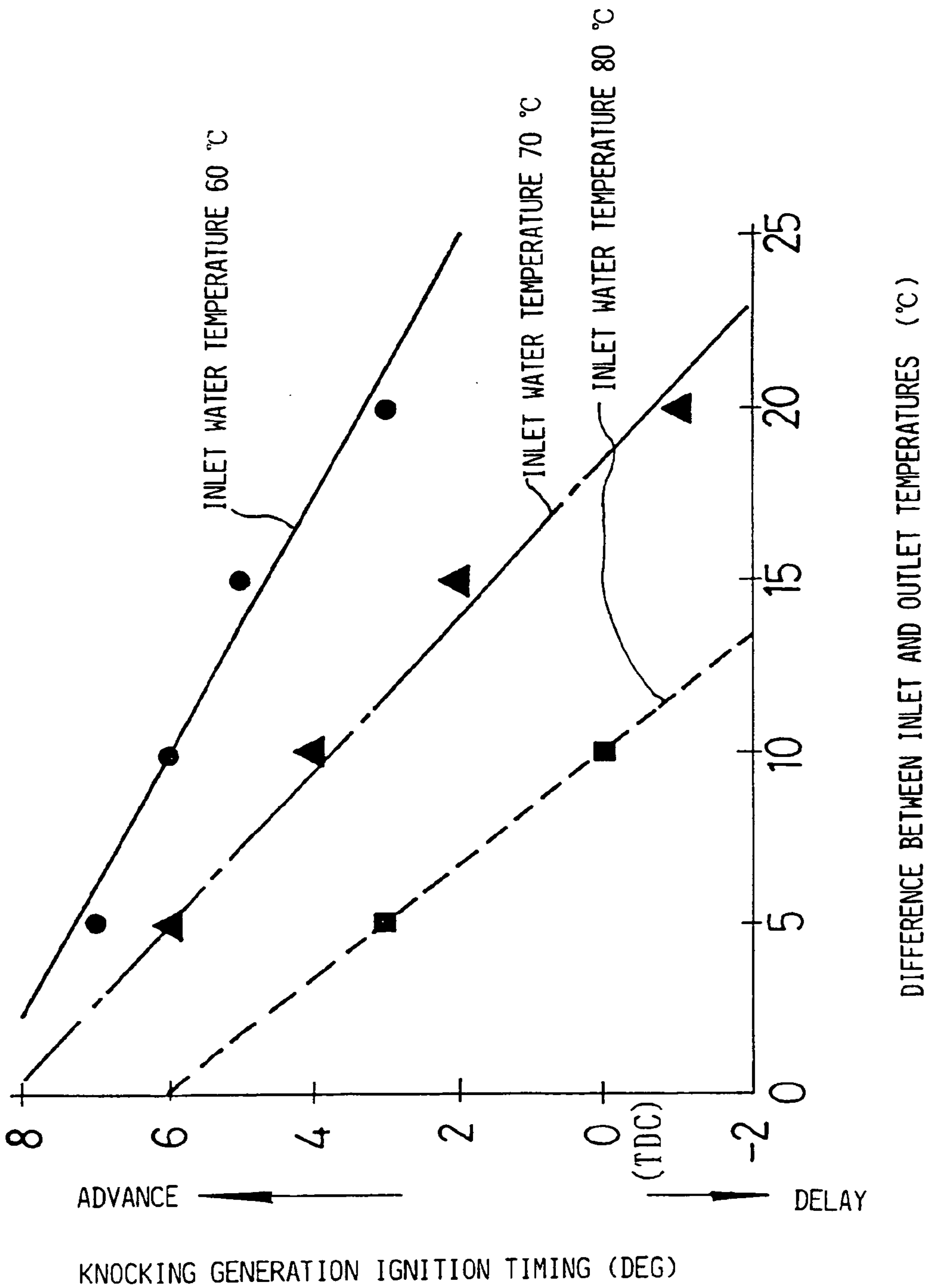

INLET WATER TEMPERATURE 60 °C
INLET WATER TEMPERATURE 70 °C
INLET WATER TEMPERATURE 80 °C
8
6
4
2
0
(TDC)
-2
0
5
10
15
20
25
ADVANCE
DELAY
KNOCKING GENERATION IGNITION TIMING (DEG)
DIFFERENCE BETWEEN INLET AND OUTLET TEMPERATURES (°C)

FIG.11

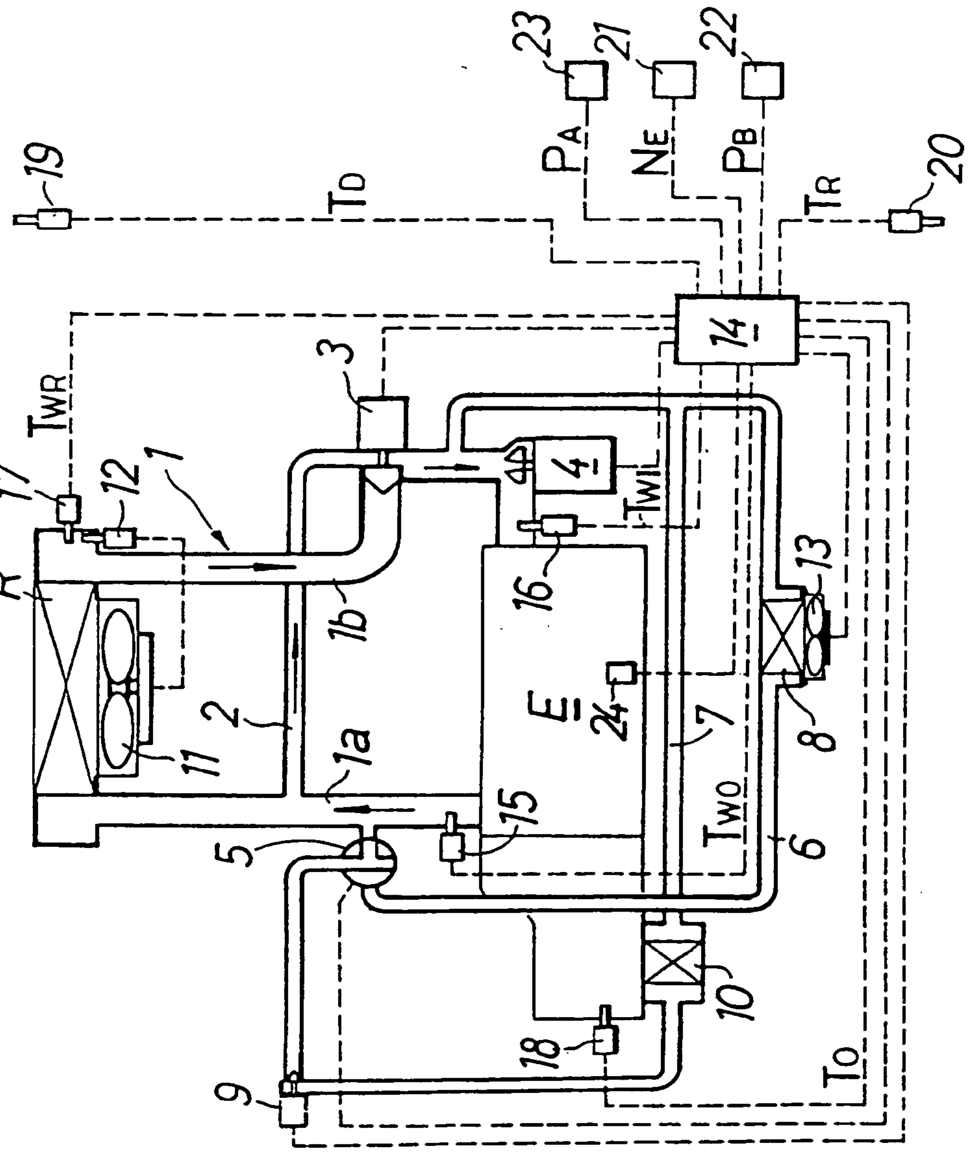

R
1
1a
1b
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
E
T_{WR}
T_{WIL}
T_{WO}
T_D
T_R
T_O
P_A
N_E
P_B

FIG.12

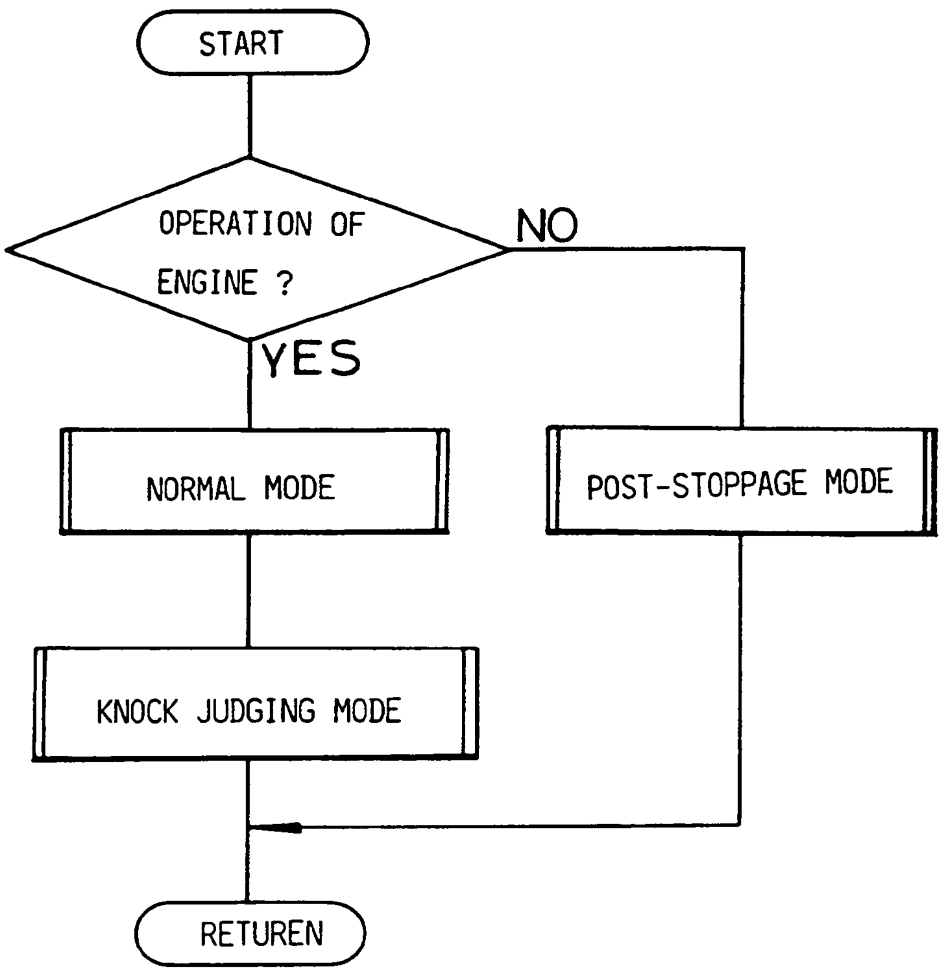

START
OPERATION OF ENGINE ?
NO
YES
NORMAL MODE
POST-STOPPAGE MODE
KNOCK JUDGING MODE
RETUREN

FIG.13

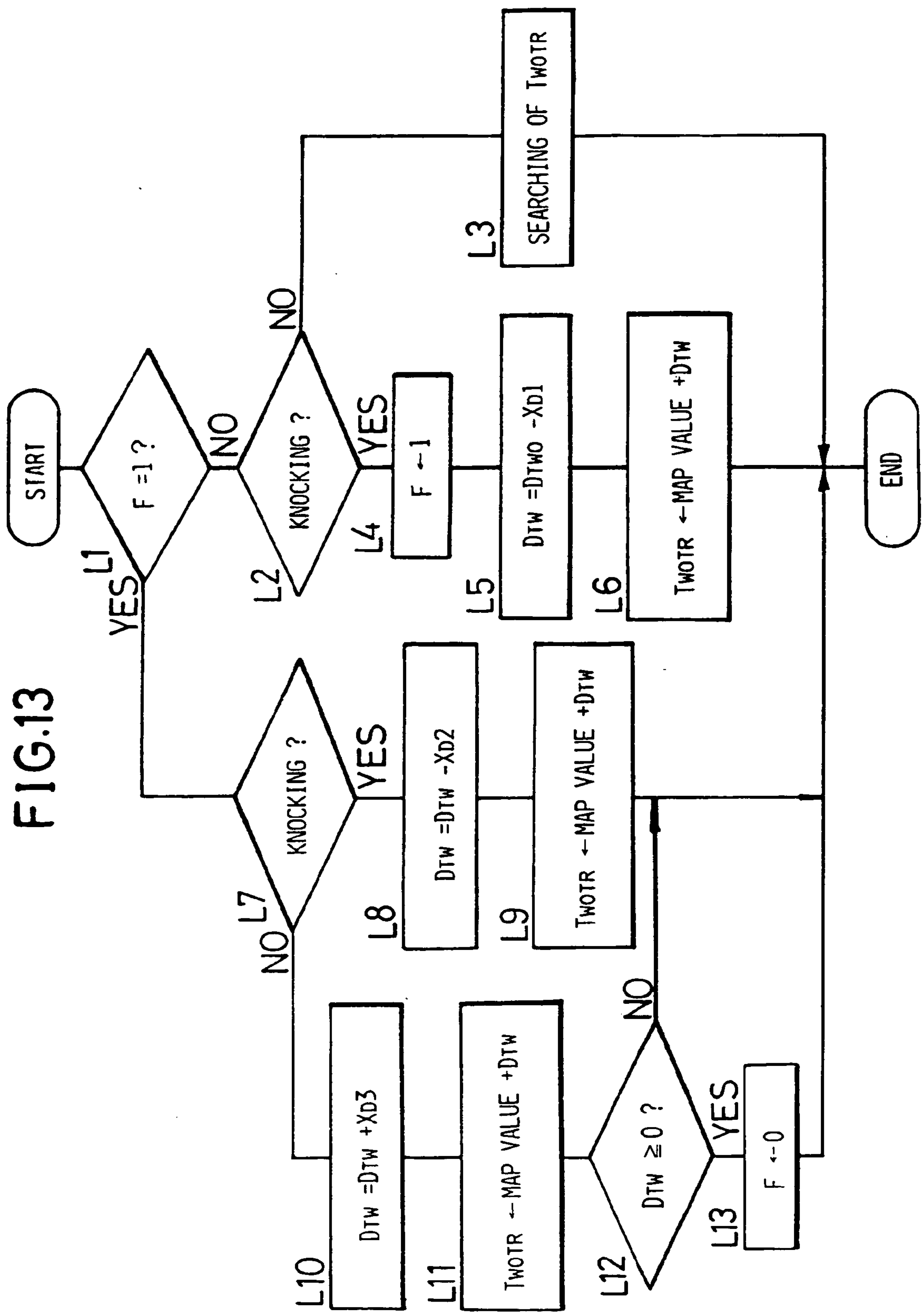

START
L1
F =1 ?
YES
NO
L2
KNOCKING ?
YES
NO
L3
SEARCHING OF TWOTR
L4
F ←1
L5
DTW =DTWO -XD1
L6
TWOTR ←MAP VALUE +DTW
END
L7
KNOCKING ?
YES
NO
L8
DTW =DTW -XD2
L9
TWOTR ←MAP VALUE +DTW
L10
DTW =DTW +XD3
L11
TWOTR ←MAP VALUE +DTW
L12
DTW ≧0 ?
NO
YES
L13
F ←0

FIG.14

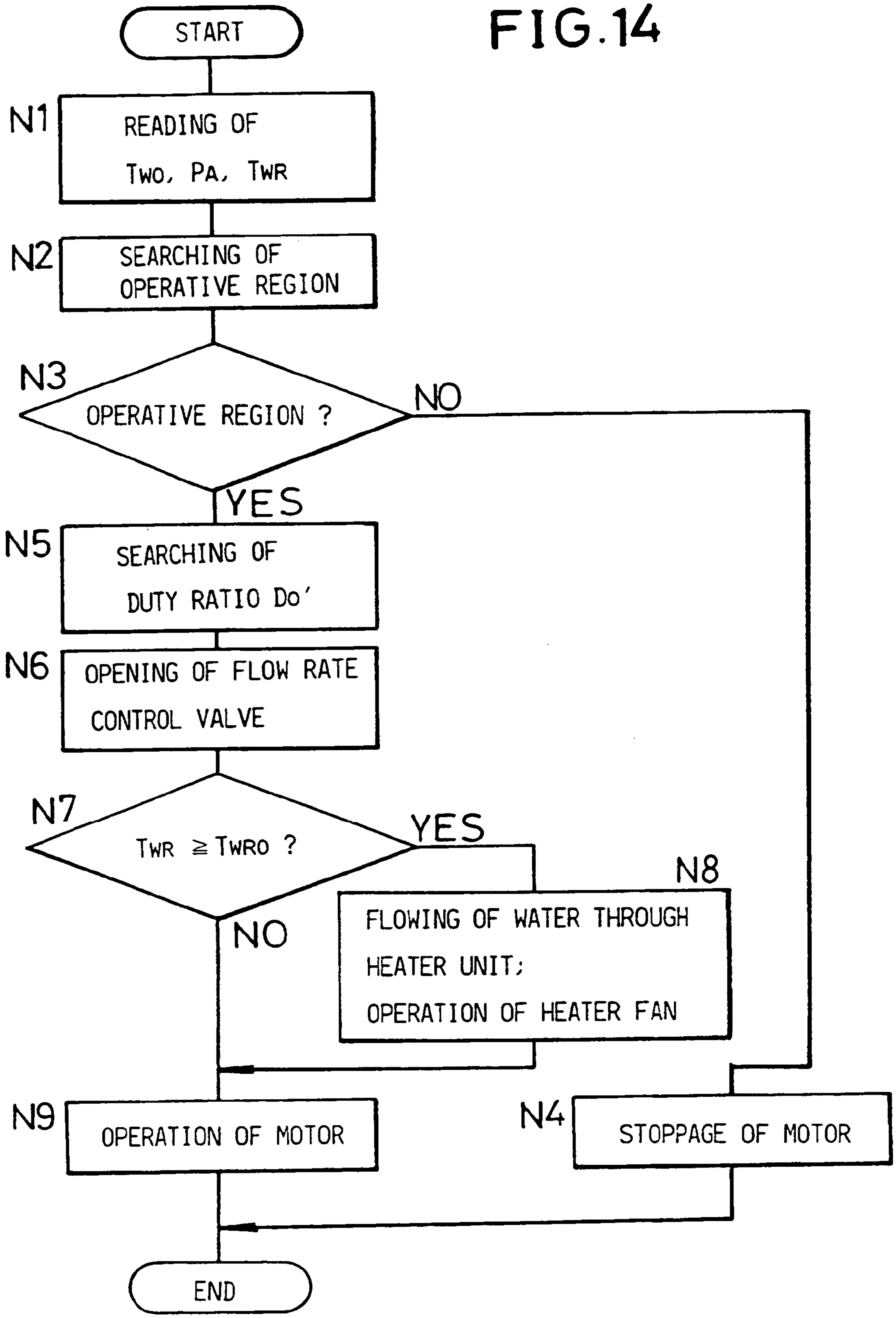

START
N1
READING OF
TWO, PA, TWR
N2
SEARCHING OF
OPERATIVE REGION
N3
OPERATIVE REGION ?
NO
YES
N5
SEARCHING OF
DUTY RATIO Do'
N6
OPENING OF FLOW RATE
CONTROL VALVE
N7
TWR ≧ TWRO ?
YES
NO
N8
FLOWING OF WATER THROUGH
HEATER UNIT;
OPERATION OF HEATER FAN
N9
OPERATION OF MOTOR
N4
STOPPAGE OF MOTOR
END

FIG.15

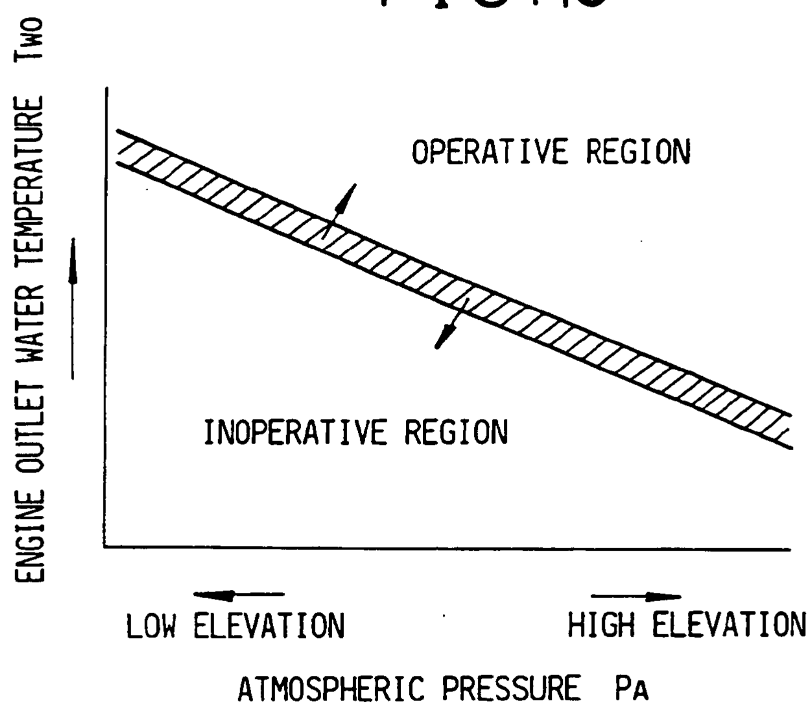

ENGINE OUTLET WATER TEMPERATURE Two
OPERATIVE REGION
INOPERATIVE REGION
LOW ELEVATION
HIGH ELEVATION
ATMOSPHERIC PRESSURE PA

FIG.16

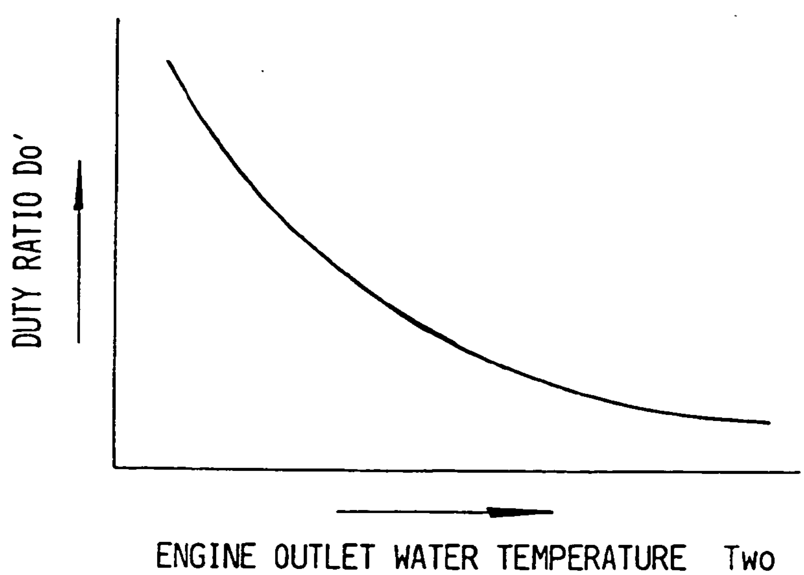

DUTY RATIO Do'
ENGINE OUTLET WATER TEMPERATURE Two

FIG.17

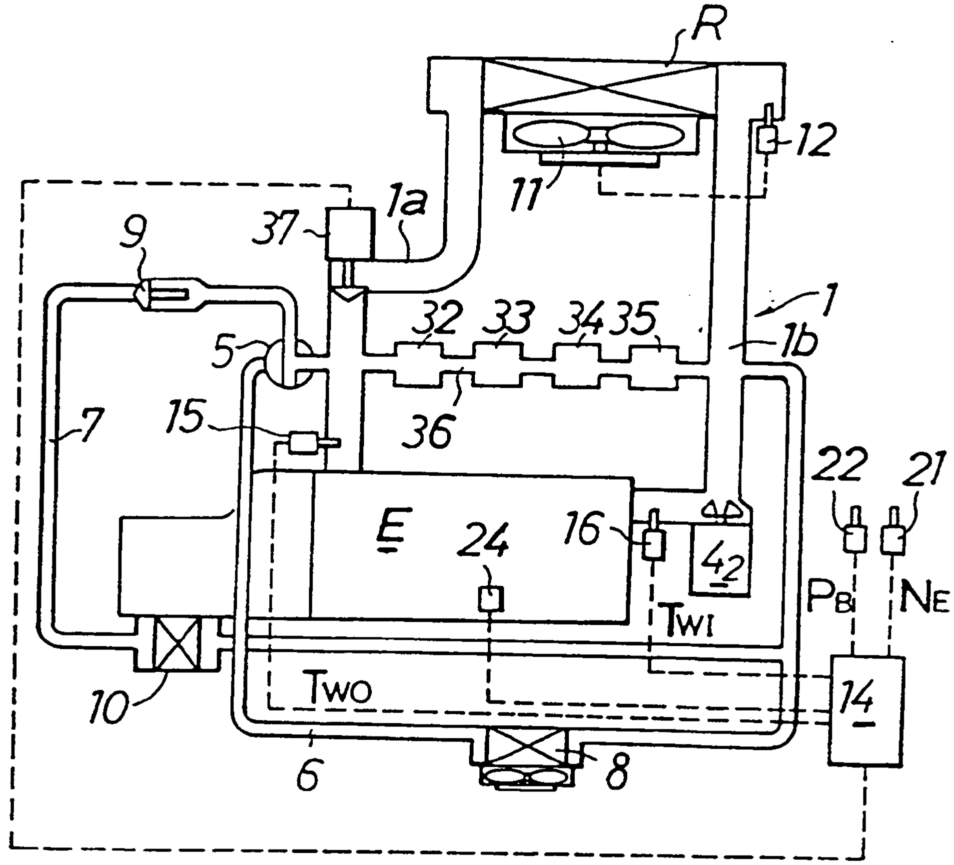

R
12
11
1a
37
9
1
32
33
34
35
1b
5
7
15
36
22
21
E
16
24
42
PB
NE
TWI
10
TWO
14
6
8

FIG.18

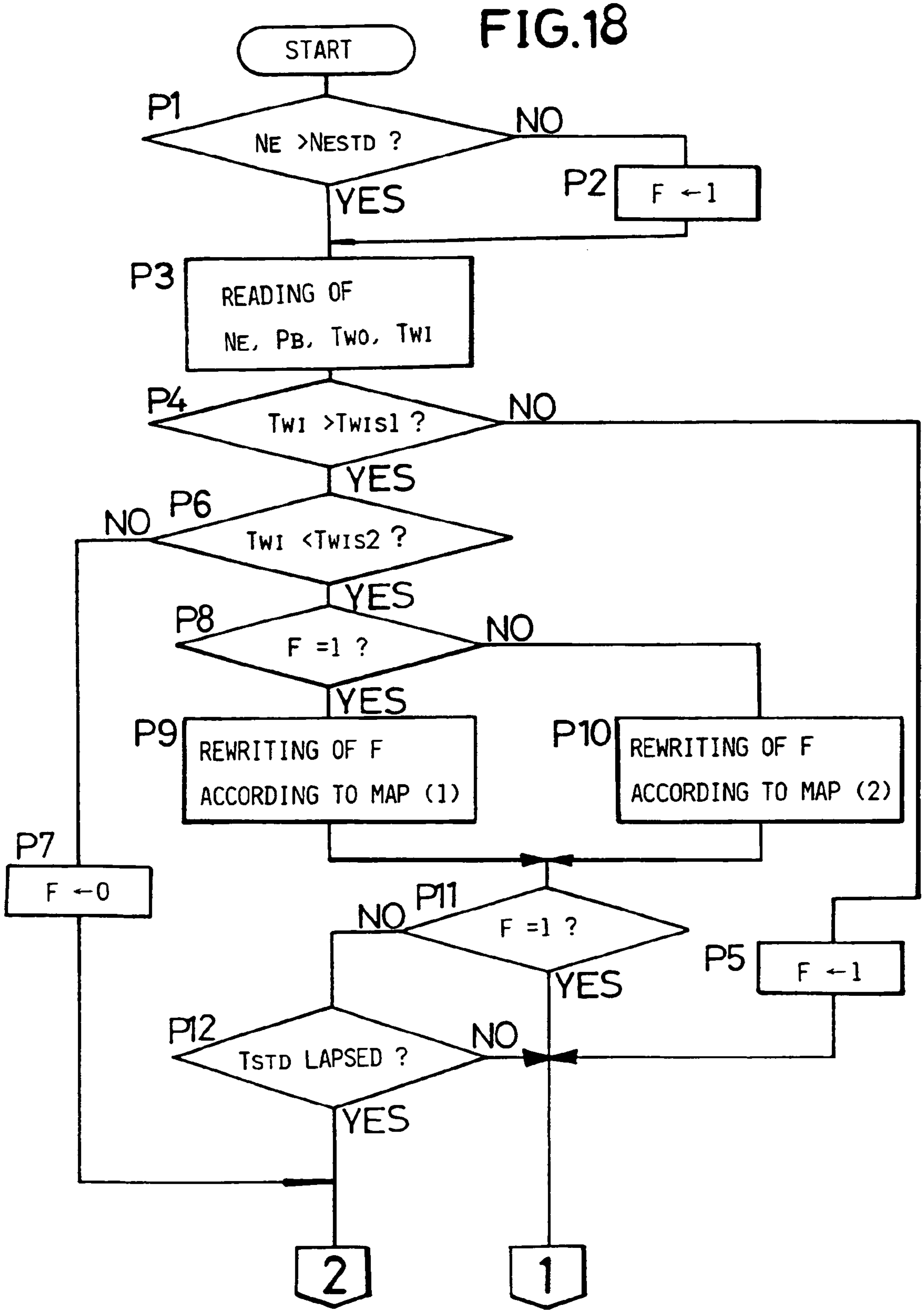

START
P1
NE >NESTD ?
NO
YES
P2
F ←1
P3
READING OF
NE, PB, TWO, TWI
P4
TWI >TWIS1 ?
NO
YES
P6
NO
TWI <TWIS2 ?
YES
P8
F =1 ?
NO
YES
P9
REWRITING OF F
ACCORDING TO MAP (1)
P10
REWRITING OF F
ACCORDING TO MAP (2)
P7
F ←0
P11
NO
F =1 ?
YES
P5
F ←1
P12
TSTD LAPSED ?
NO
YES
2
1

FIG.19

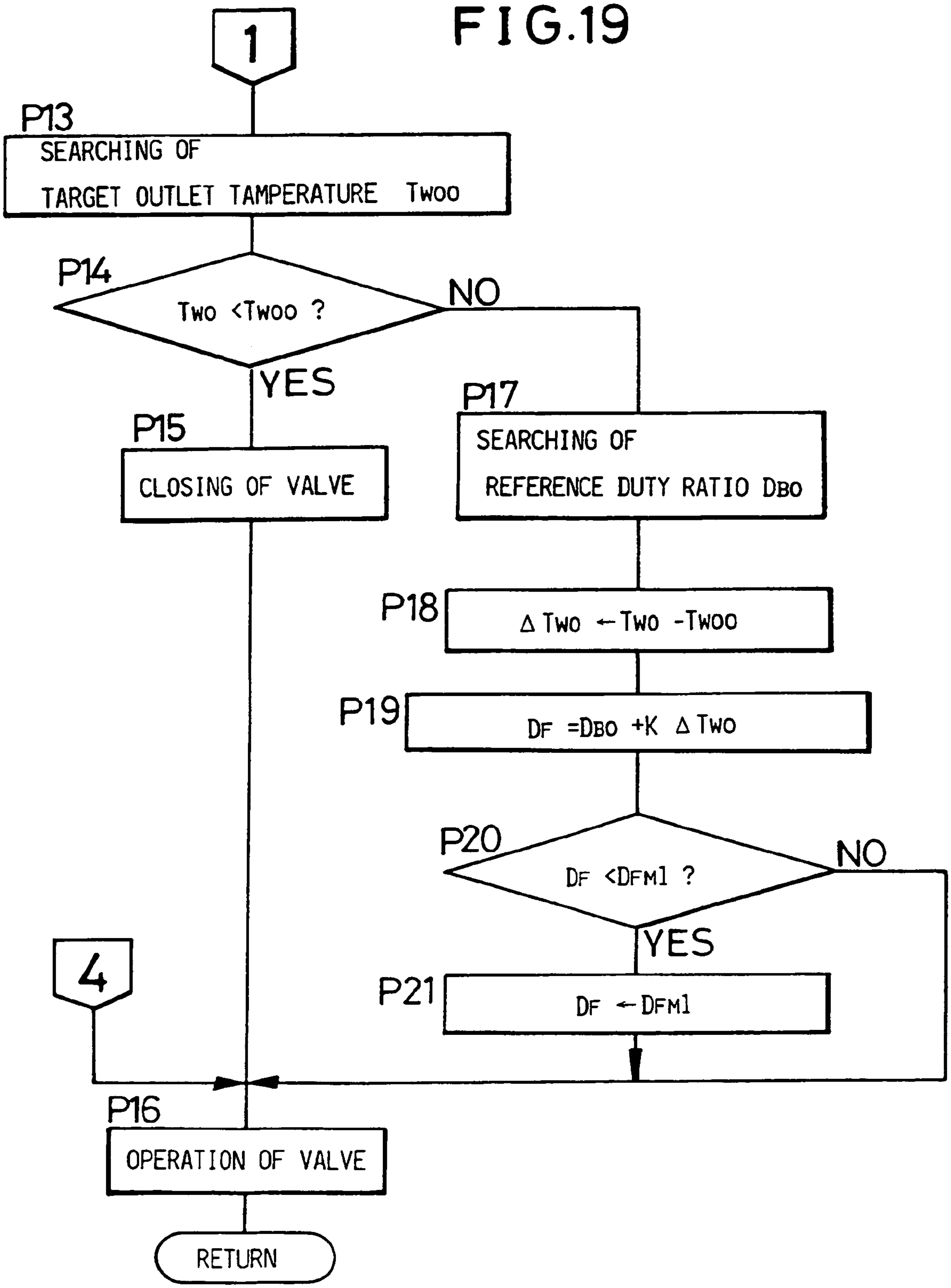

1
P13
SEARCHING OF
TARGET OUTLET TAMPERATURE Twoo
P14
Two <Twoo ?
NO
YES
P15
CLOSING OF VALVE
P17
SEARCHING OF
REFERENCE DUTY RATIO DBO
P18
Δ Two ← Two - Twoo
P19
DF = DBO + K Δ Two
P20
DF < DFM1 ?
NO
YES
P21
DF ← DFM1
4
P16
OPERATION OF VALVE
RETURN

FIG.20

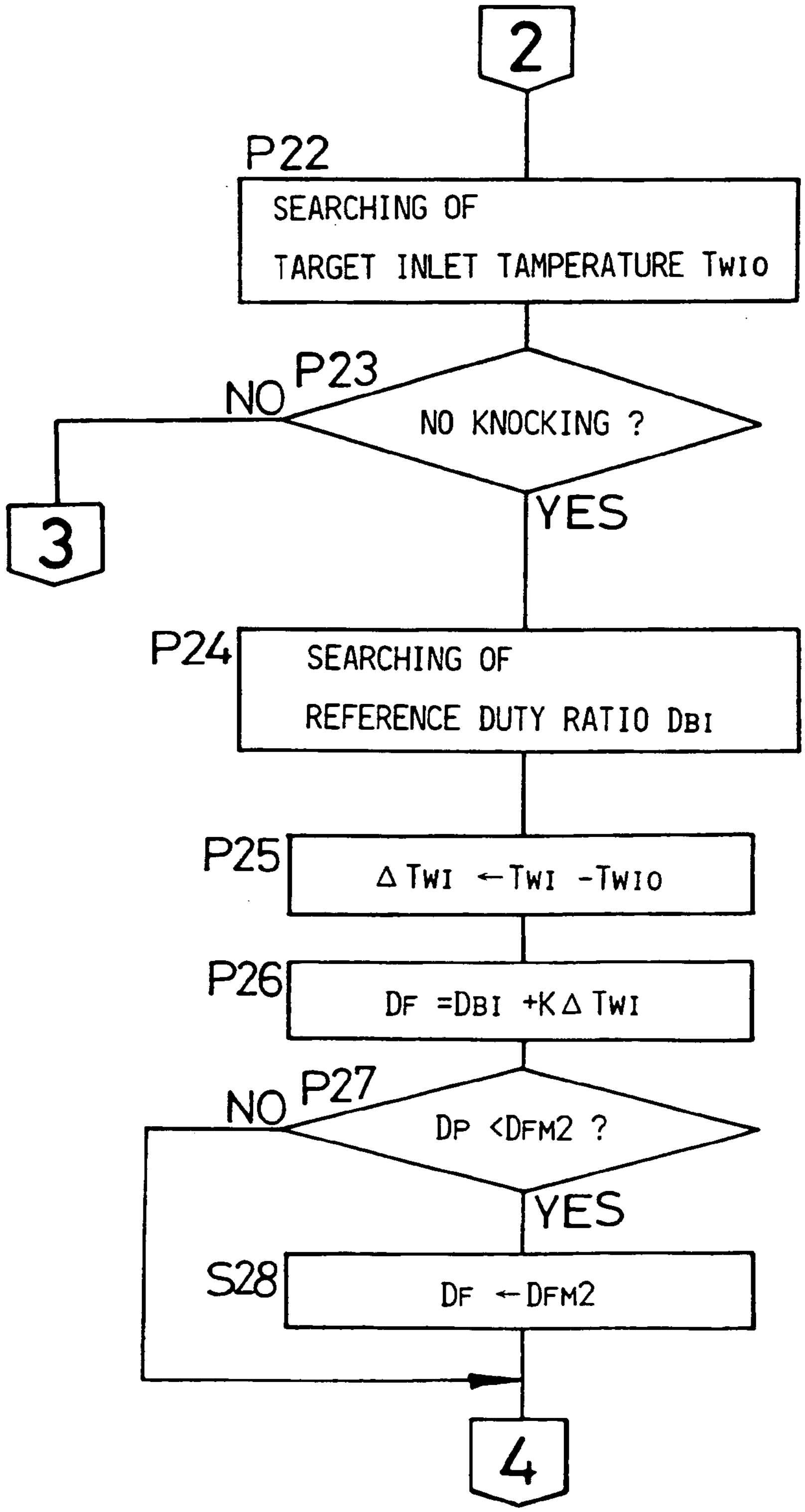

2
P22
SEARCHING OF
TARGET INLET TAMPERATURE TWIO
NO
P23
NO KNOCKING ?
3
YES
P24
SEARCHING OF
REFERENCE DUTY RATIO DBI
P25
ΔTWI ←TWI -TWIO
P26
DF =DBI +KΔTWI
NO
P27
DP <DFM2 ?
YES
S28
DF ←DFM2
4

FIG.21

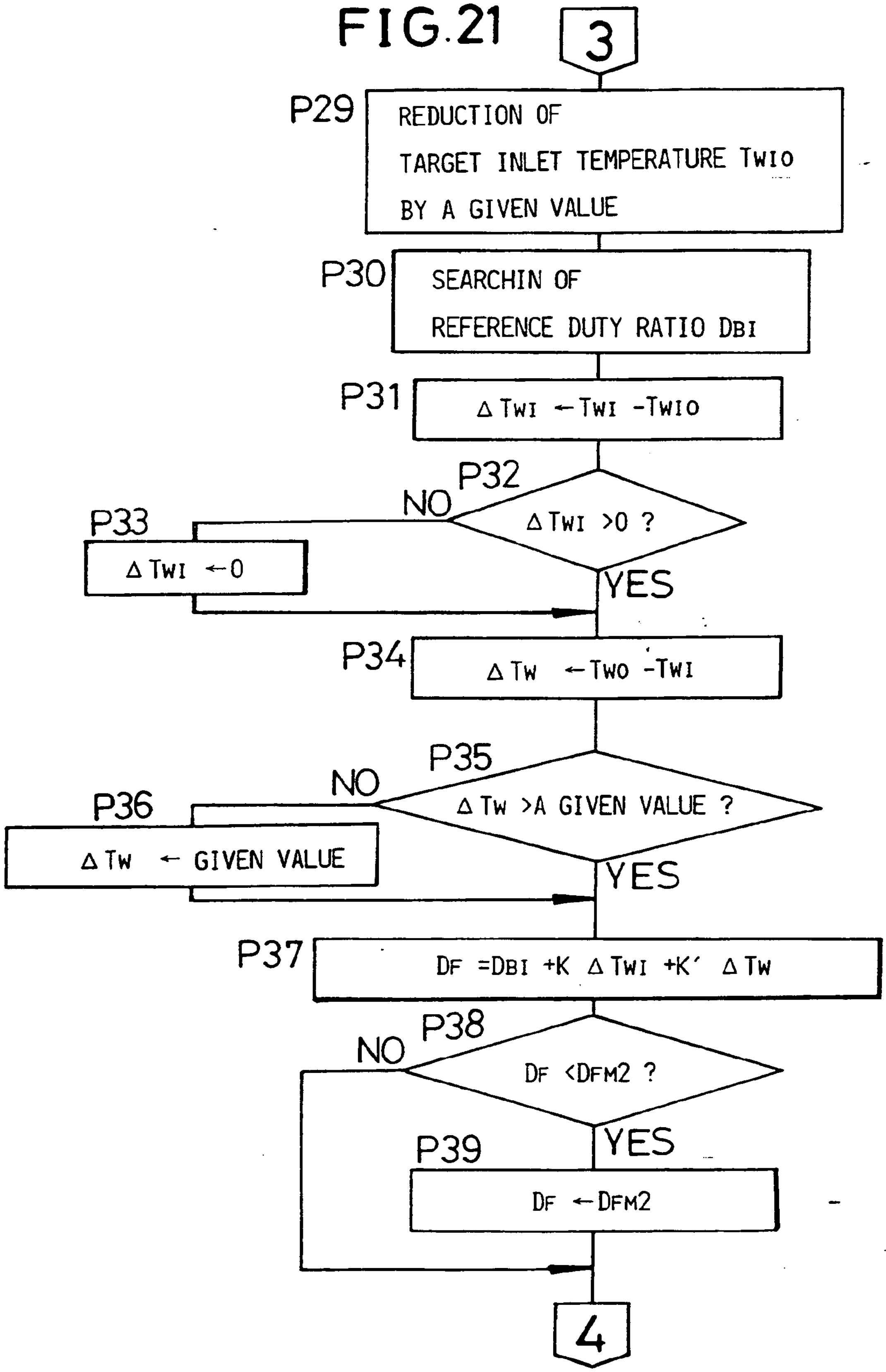

3
P29
REDUCTION OF
TARGET INLET TEMPERATURE TWIO
BY A GIVEN VALUE
P30
SEARCHIN OF
REFERENCE DUTY RATIO DBI
P31
ΔTWI ←TWI -TWIO
P32
ΔTWI >0 ?
NO
YES
P33
ΔTWI ←0
P34
ΔTW ←TWO -TWI
P35
ΔTW >A GIVEN VALUE ?
NO
YES
P36
ΔTW ← GIVEN VALUE
P37
DF =DBI +K ΔTWI +K′ ΔTW
P38
DF <DFM2 ?
NO
YES
P39
DF ←DFM2
4

FIG.22

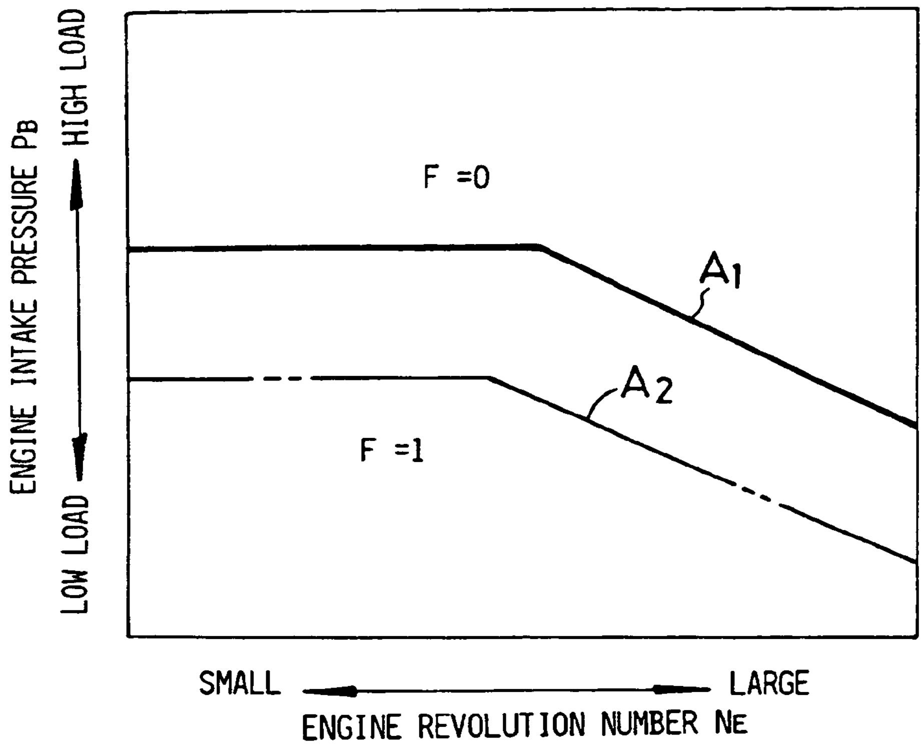

ENGINE INTAKE PRESSURE PB
HIGH LOAD
LOW LOAD
F =0
A1
A2
F =1
SMALL
LARGE
ENGINE REVOLUTION NUMBER NE

FIG.23

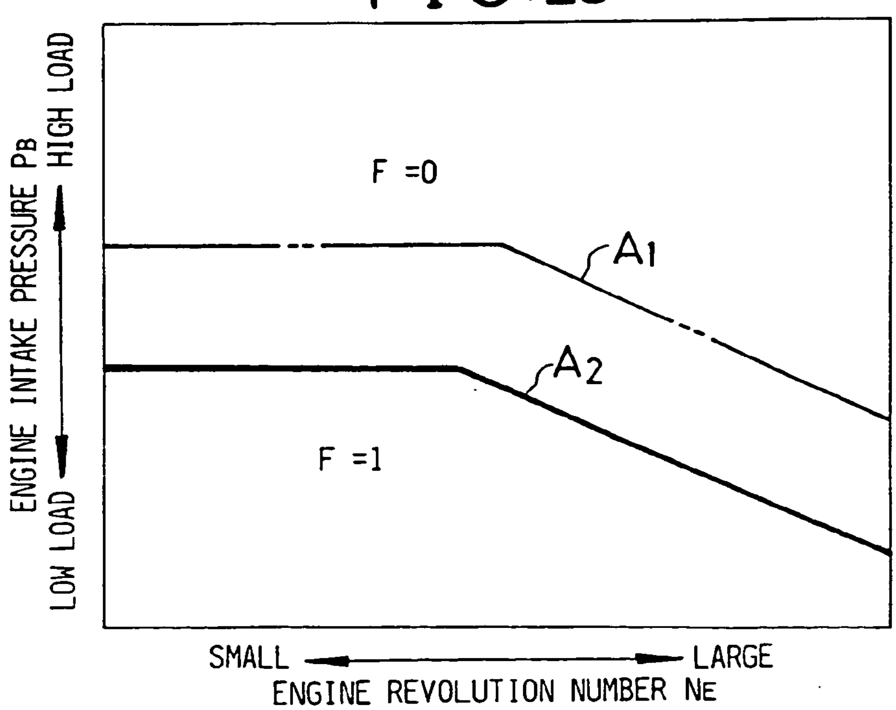

ENGINE INTAKE PRESSURE PB
HIGH LOAD
LOW LOAD
F =0
A1
A2
F =1
SMALL
LARGE
ENGINE REVOLUTION NUMBER NE

FIG.24

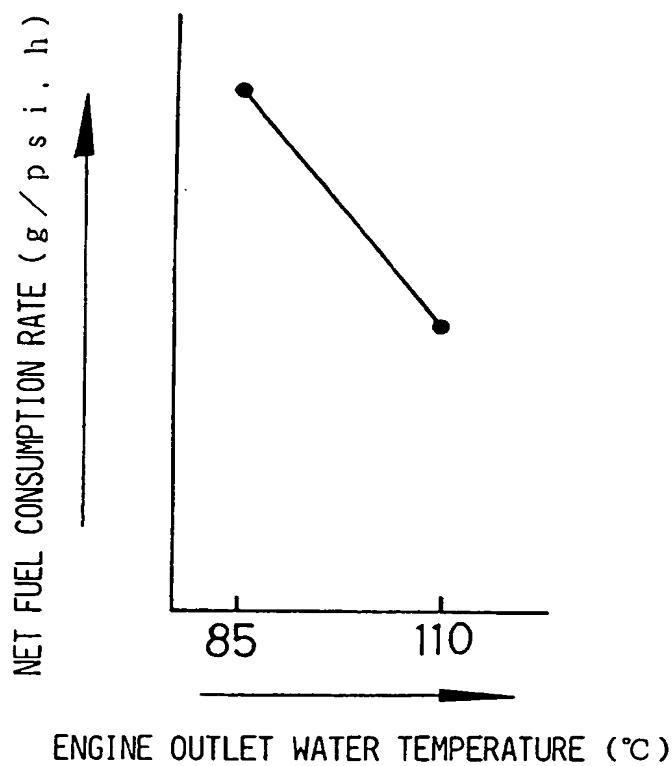

NET FUEL CONSUMPTION RATE (g/psi.h)
85
110
ENGINE OUTLET WATER TEMPERATURE (℃)

FIG.25

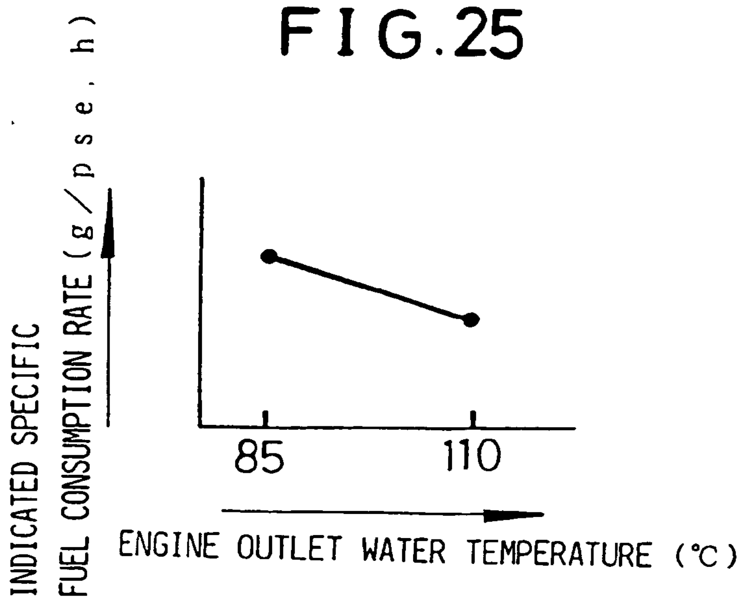

INDICATED SPECIFIC
FUEL CONSUMPTION RATE (g/pse.h)
85
110
ENGINE OUTLET WATER TEMPERATURE (℃)

FIG. 26

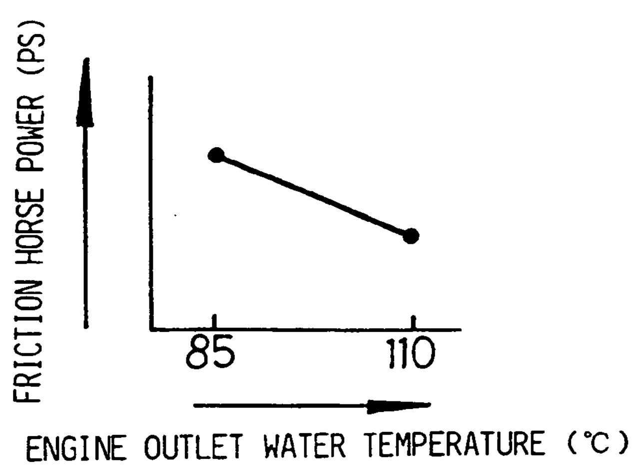

FRICTION HORSE POWER (PS)
85
110
ENGINE OUTLET WATER TEMPERATURE (℃)

FIG. 27

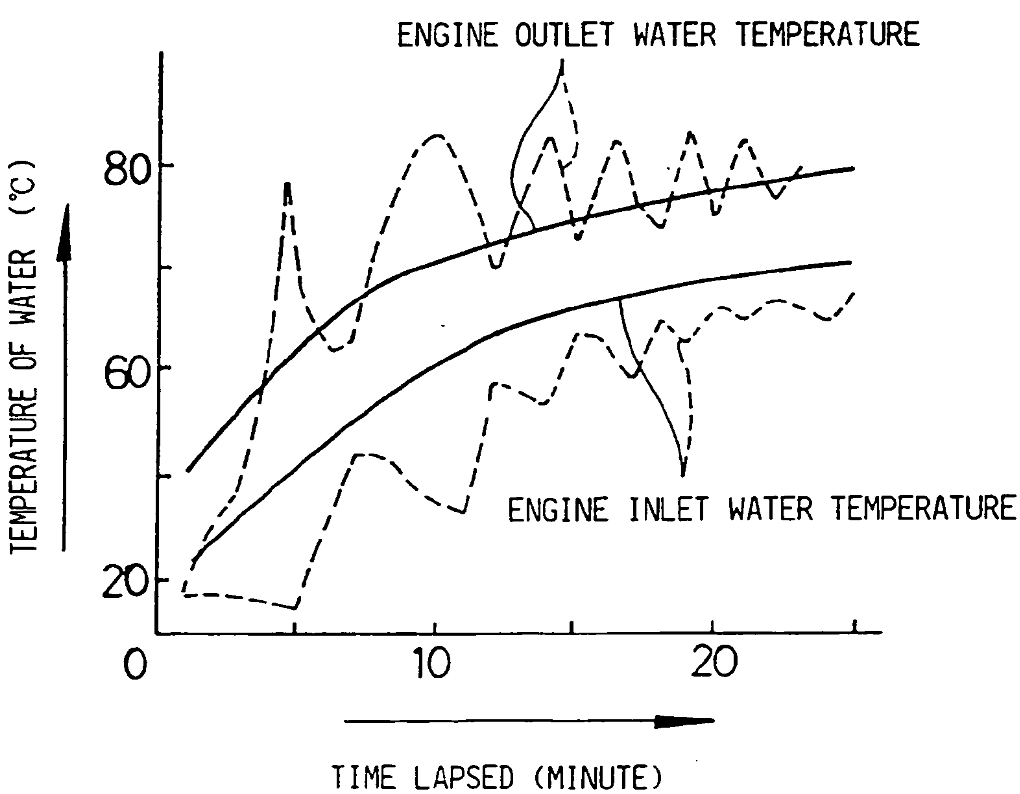

ENGINE OUTLET WATER TEMPERATURE
TEMPERATURE OF WATER (℃)
80
60
20
0
10
20
ENGINE INLET WATER TEMPERATURE
TIME LAPSED (MINUTE)

FIG. 28

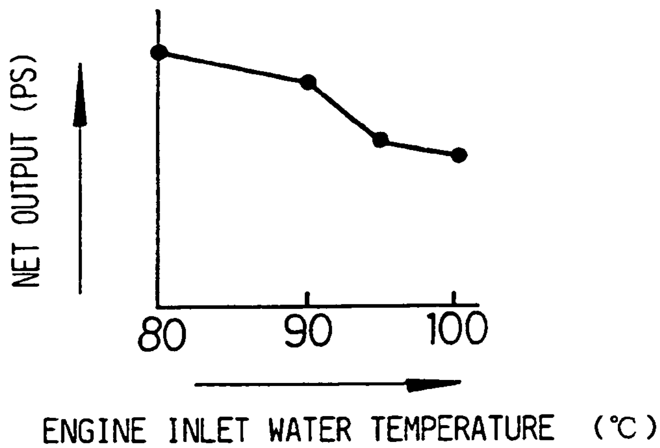

NET OUTPUT (PS)
80
90
100
ENGINE INLET WATER TEMPERATURE (℃)

FIG. 29

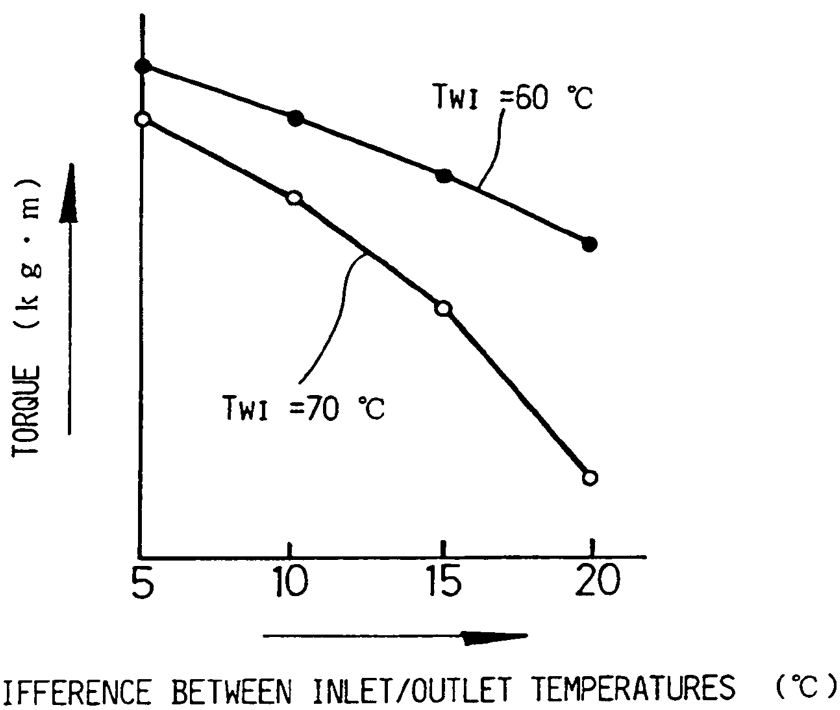
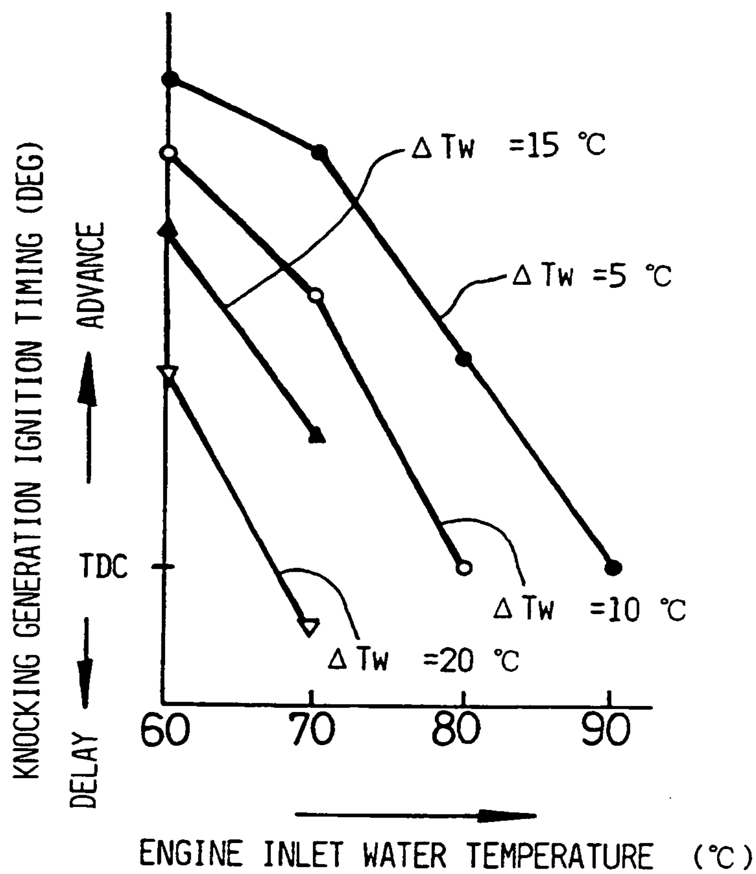

TORQUE (kg · m)
TWI =60 ℃
TWI =70 ℃
5
10
15
20
DIFFERENCE BETWEEN INLET/OUTLET TEMPERATURES (℃)

FIG.30


KNOCKING GENERATION IGNITION TIMING (DEG)
ADVANCE
DELAY
TDC
ΔTw =15 ℃
ΔTw =5 ℃
ΔTw =10 ℃
ΔTw =20 ℃
60
70
80
90
ENGINE INLET WATER TEMPERATURE (℃)

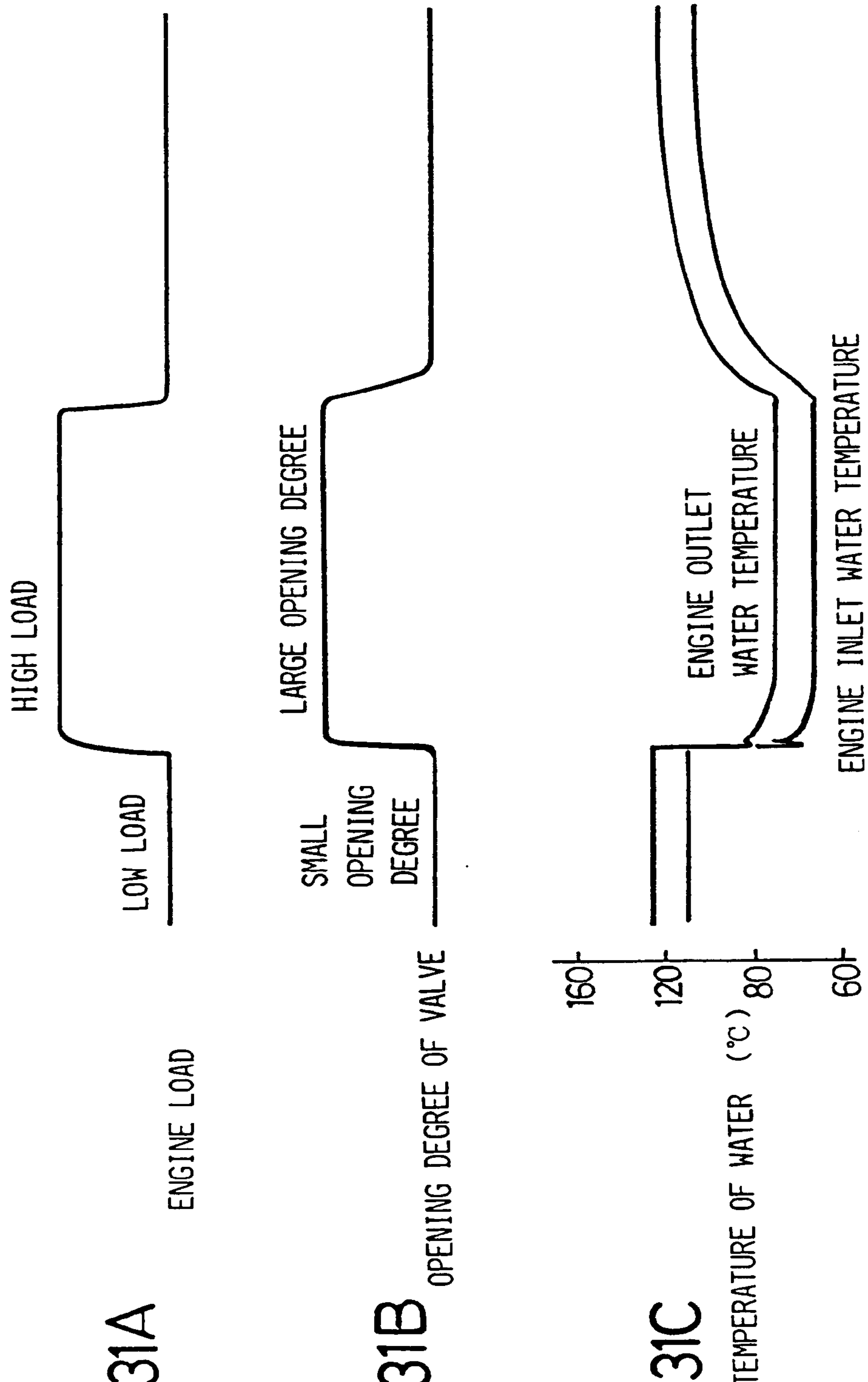
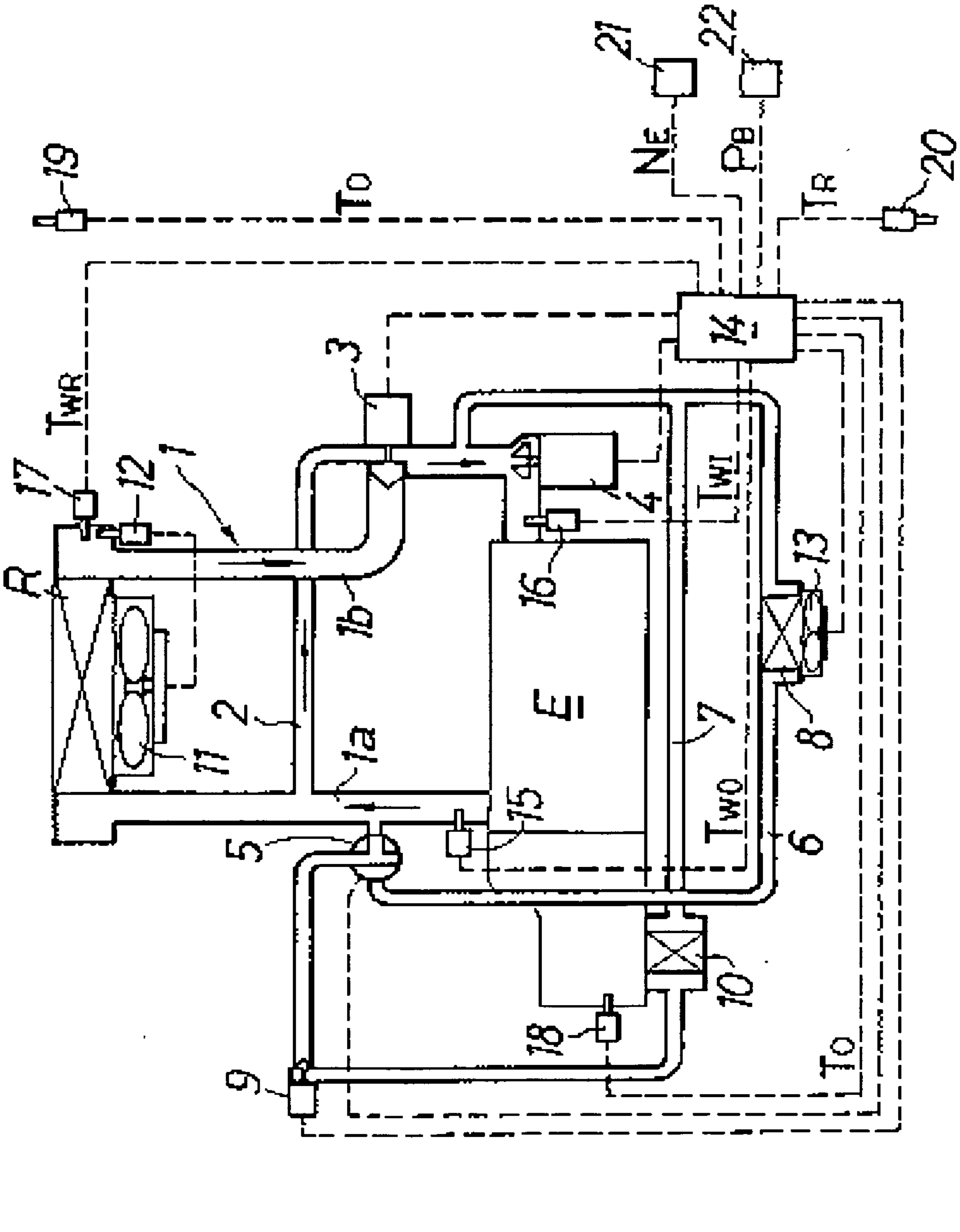


FIG.31A

FIG.31B

FIG.31C

FIG.1



19
T_O
21
22
N_E
P_B
T_R
20
14
3
1
12
17
T_{WR}
R
11
2
1a
1b
5
15
16
4
T_{WI}
E
7
T_{WO}
6
8
13
10
18
9
T_O

FIG. 2

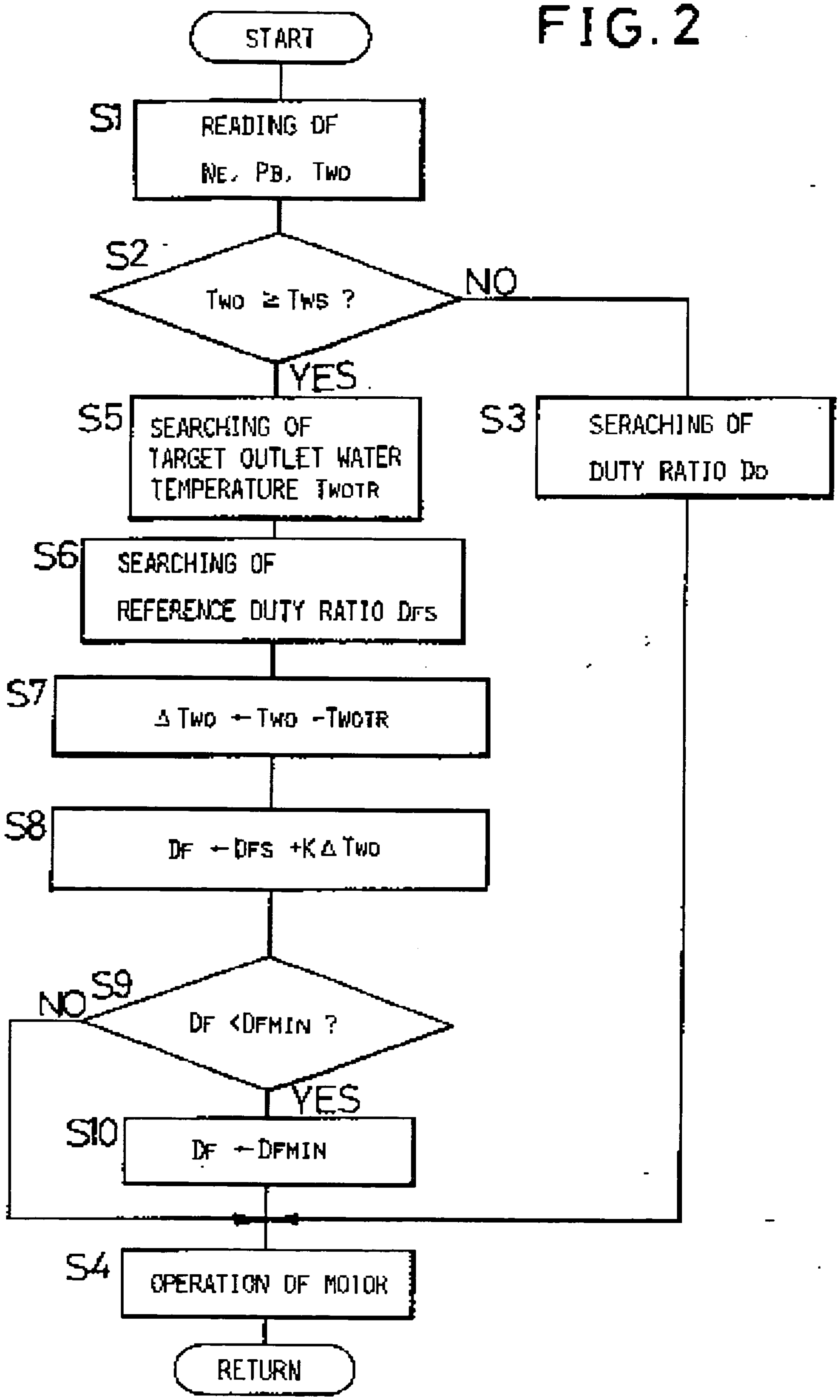

START
S1
READING OF
NE, PB, TWO
S2
TWO ≥ TWS ?
NO
YES
S5
SEARCHING OF
TARGET OUTLET WATER
TEMPERATURE TWOTR
S3
SERACHING OF
DUTY RATIO DO
S6
SEARCHING OF
REFERENCE DUTY RATIO DFS
S7
Δ TWO ← TWO - TWOTR
S8
DF ← DFS + K Δ TWO
S9
NO
DF < DFMIN ?
YES
S10
DF ← DFMIN
S4
OPERATION OF MOTOR
RETURN

FIG.3

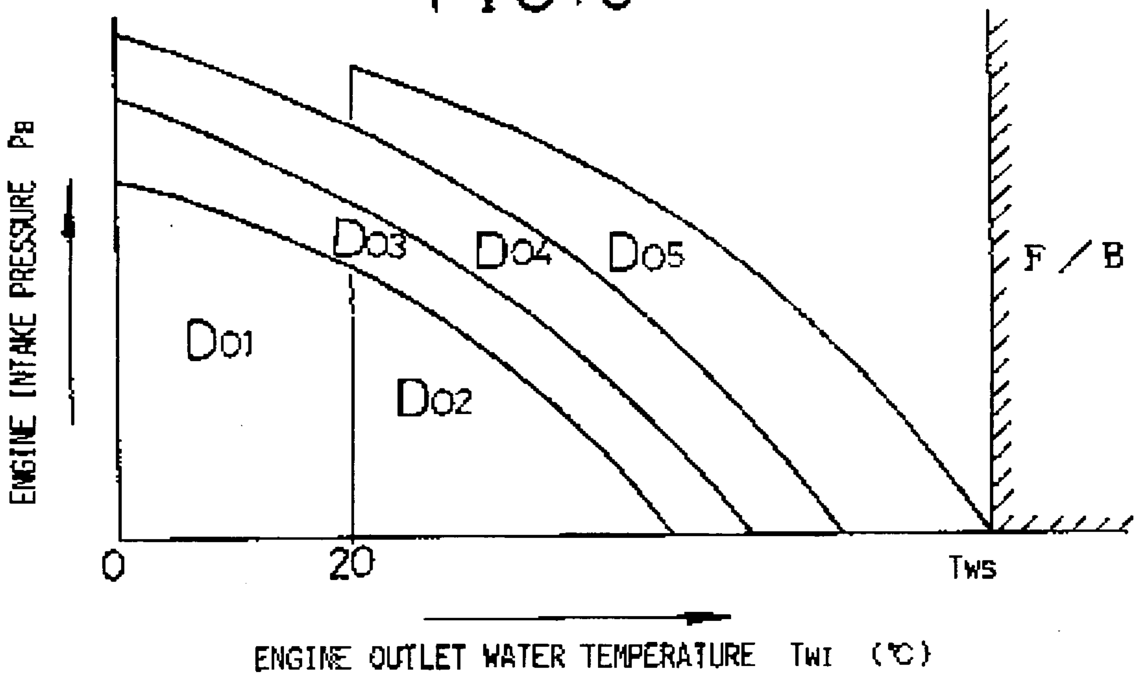

ENGINE INTAKE PRESSURE PB
Do1
Do2
Do3
Do4
Do5
F / B
0
20
TWS
ENGINE OUTLET WATER TEMPERATURE TWI (℃)

FIG.4

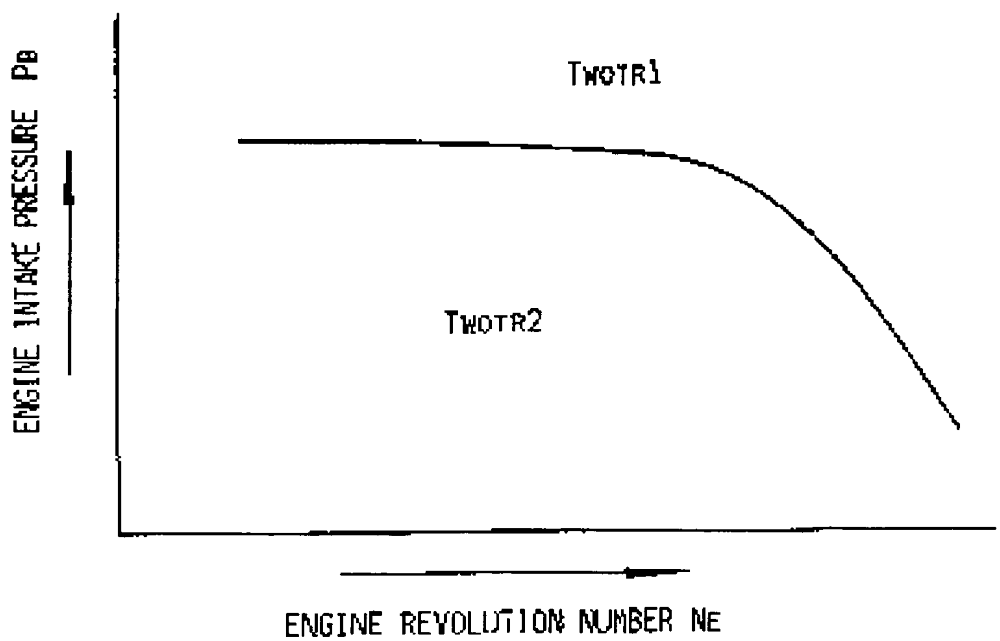

ENGINE INTAKE PRESSURE PB
TWOTR1
TWOTR2
ENGINE REVOLUTION NUMBER NE

FIG.5

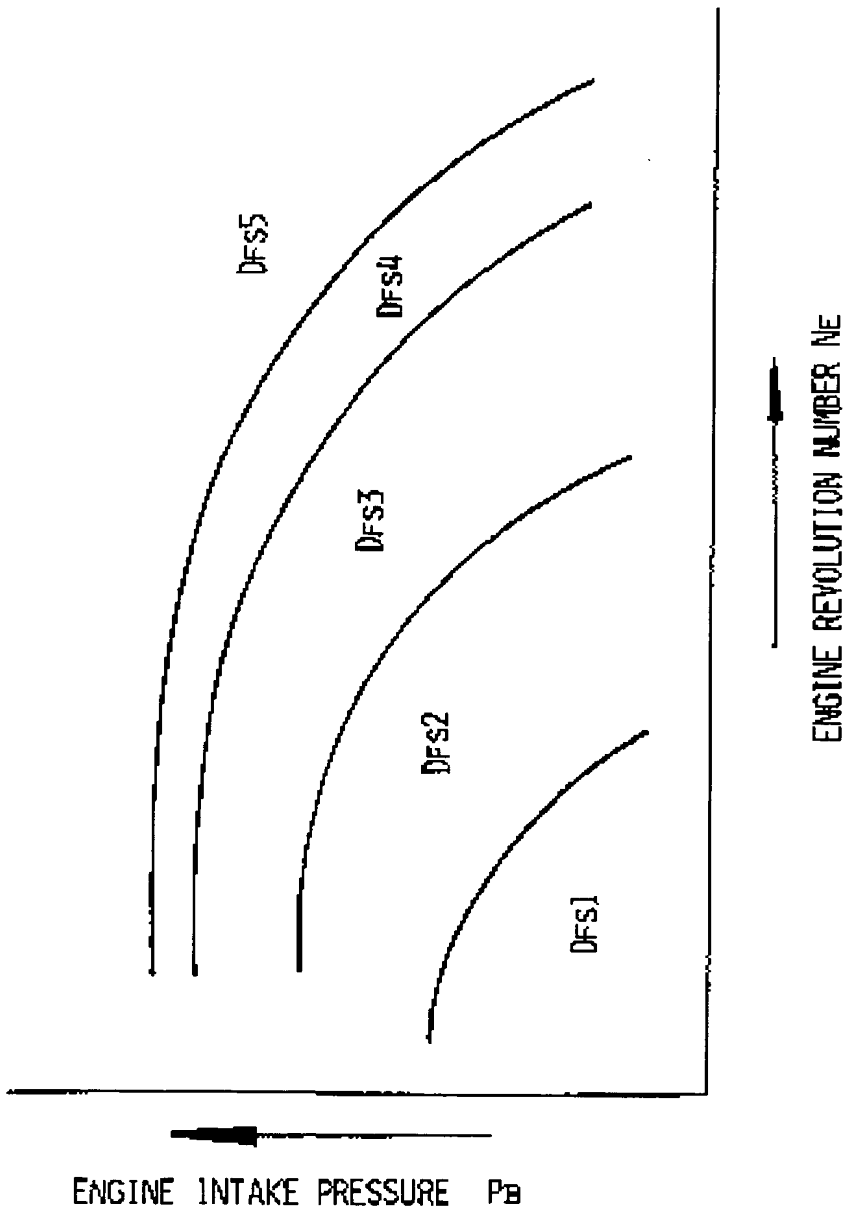

DFS5
DFS4
DFS3
DFS2
DFS1
ENGINE REVOLUTION NUMBER NE
ENGINE INTAKE PRESSURE PB

FIG.6

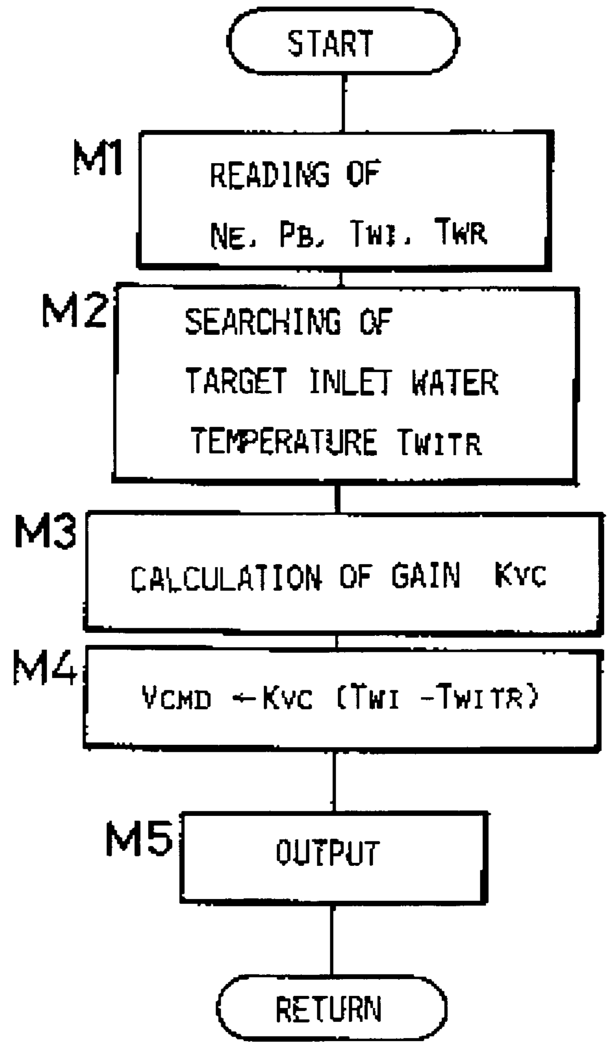

START
M1
READING OF
NE, PB, TWI, TWR
M2
SEARCHING OF
TARGET INLET WATER
TEMPERATURE TWITR
M3
CALCULATION OF GAIN KVC
M4
VCMD ← KVC (TWI - TWITR)
M5
OUTPUT
RETURN

FIG.7

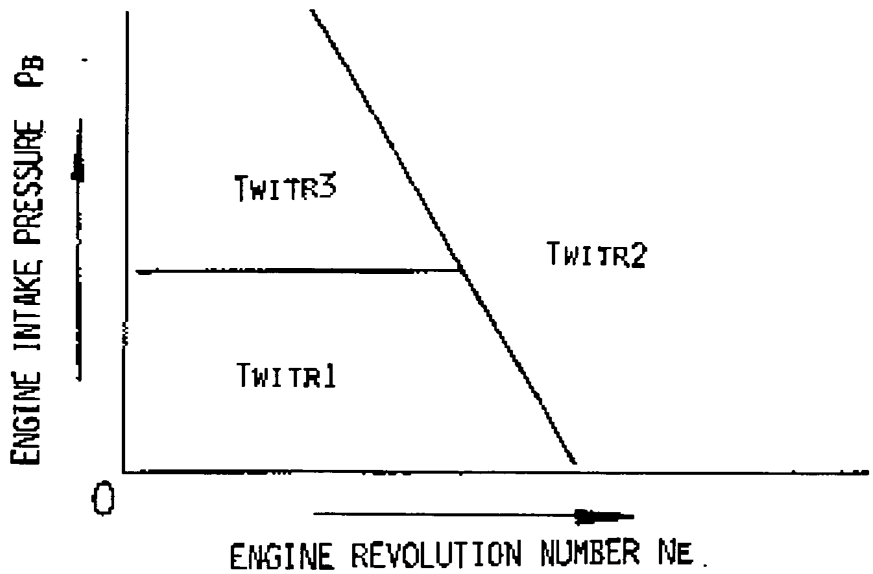

ENGINE INTAKE PRESSURE PB
TWITR3
TWITR2
TWITR1
0
ENGINE REVOLUTION NUMBER NE

FIG.8

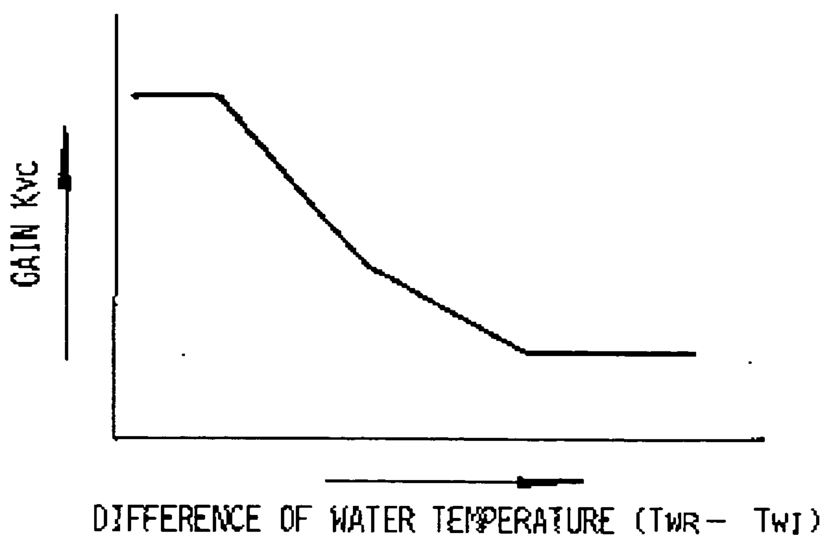

GAIN KVC
DIFFERENCE OF WATER TEMPERATURE (TWR - TWI)

FIG.9

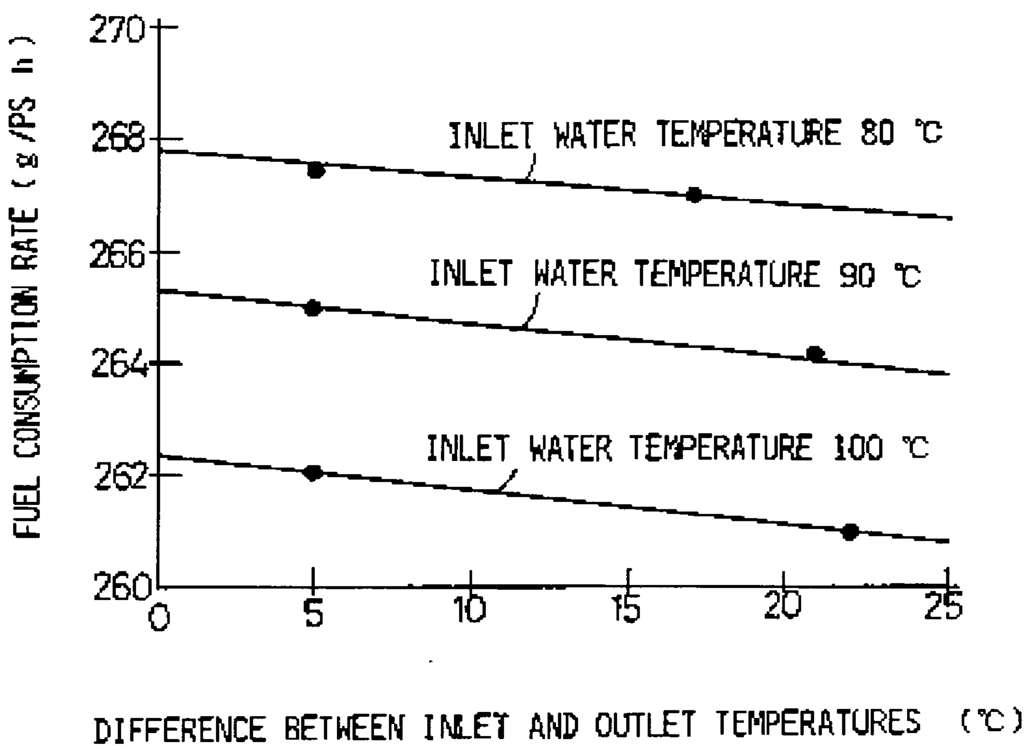

270
268
266
264
262
260
FUEL CONSUMPTION RATE (g /PS h)
INLET WATER TEMPERATURE 80 ℃
INLET WATER TEMPERATURE 90 ℃
INLET WATER TEMPERATURE 100 ℃
0
5
10
15
20
25
DIFFERENCE BETWEEN INLET AND OUTLET TEMPERATURES (℃)

FIG.10

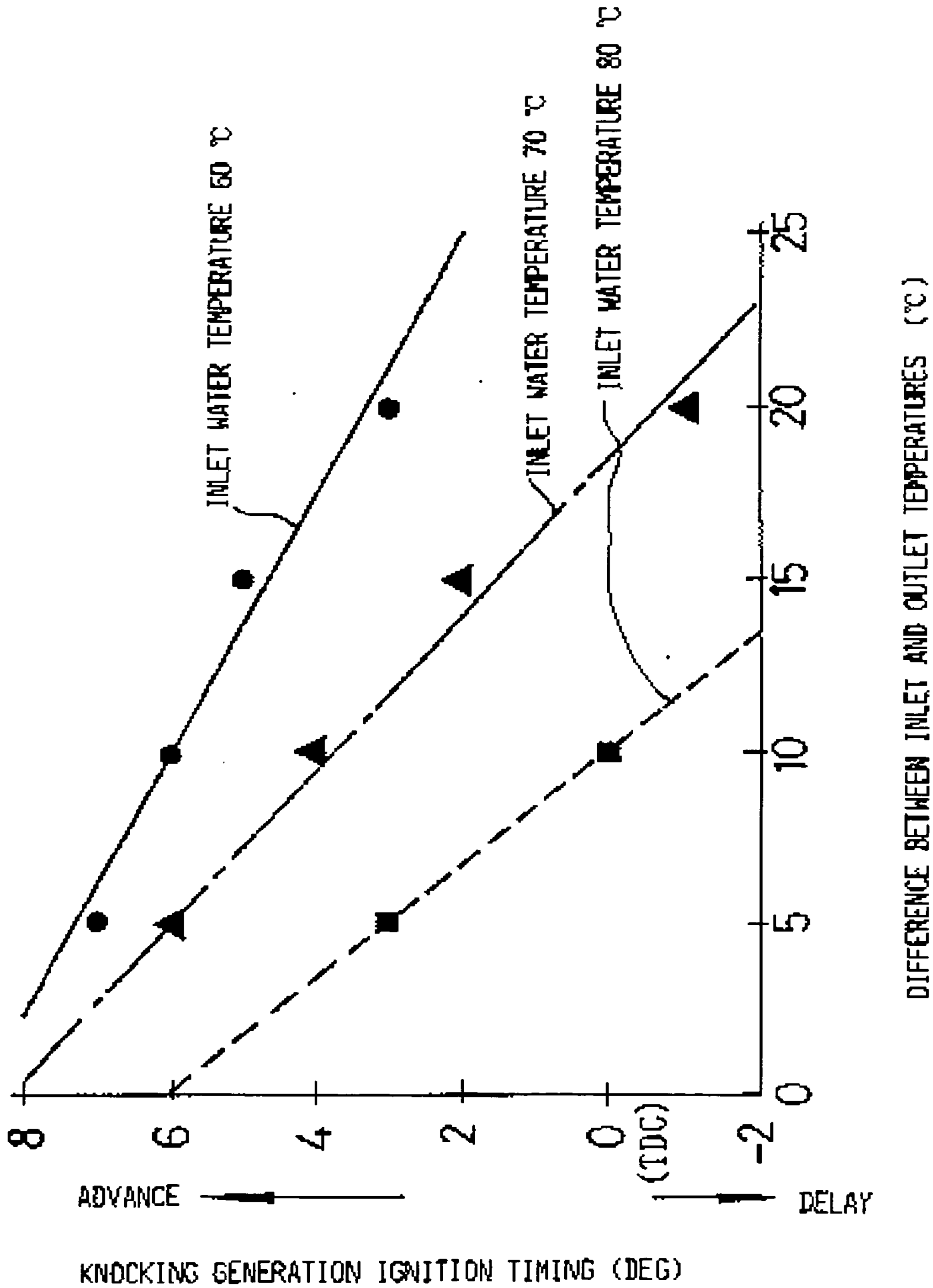

INLET WATER TEMPERATURE 60 ℃
INLET WATER TEMPERATURE 70 ℃
INLET WATER TEMPERATURE 80 ℃
8
6
4
2
0
(TDC)
-2
ADVANCE
DELAY
KNOCKING GENERATION IGNITION TIMING (DEG)
0
5
10
15
20
25
DIFFERENCE BETWEEN INLET AND OUTLET TEMPERATURES (℃)

FIG.11

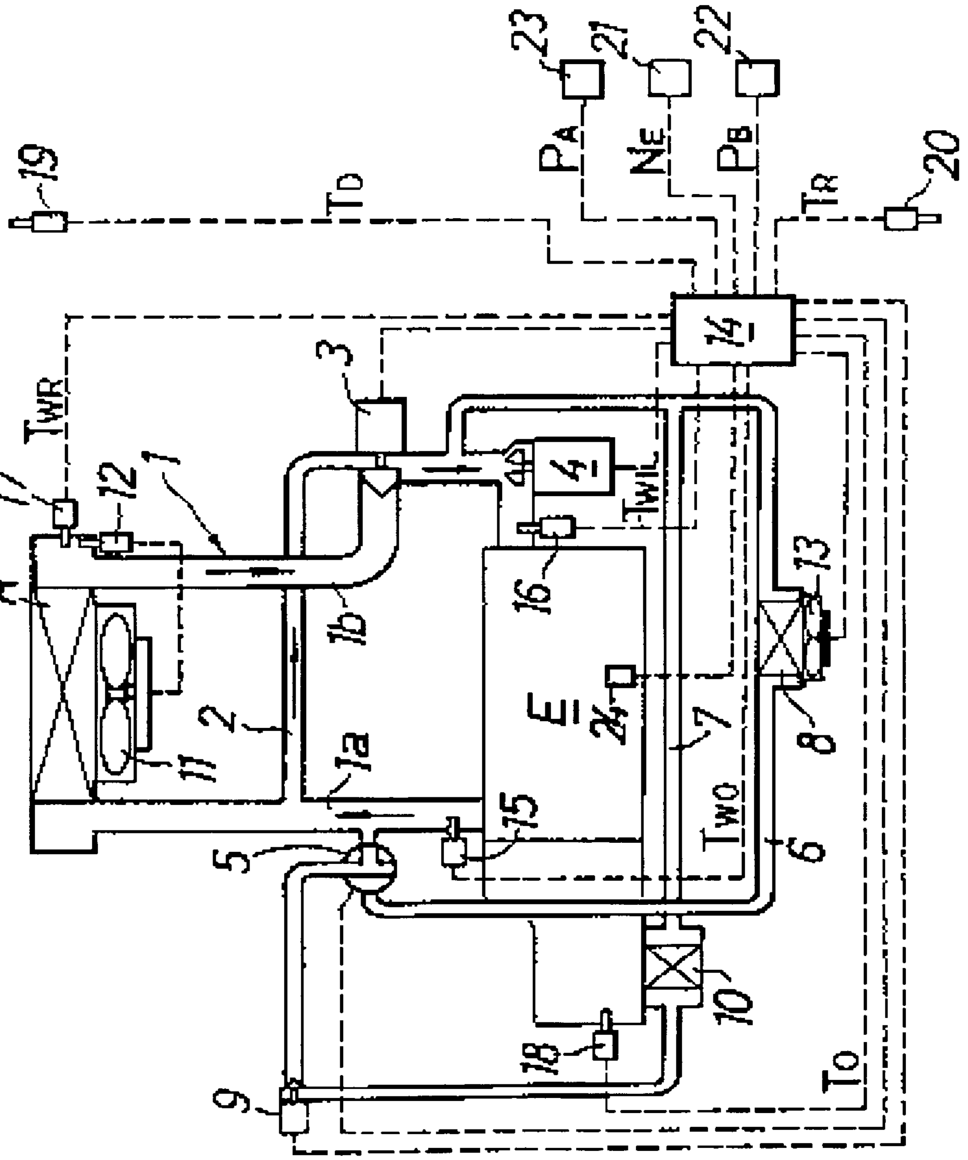

R
17
12
1
TWR
11
2
1a
1b
3
4
TWL
5
15
16
E
24
7
TWO
6
8
13
14
10
18
9
TO
19
TD
PA
NE
PB
TR
20
23
21
22

FIG.12

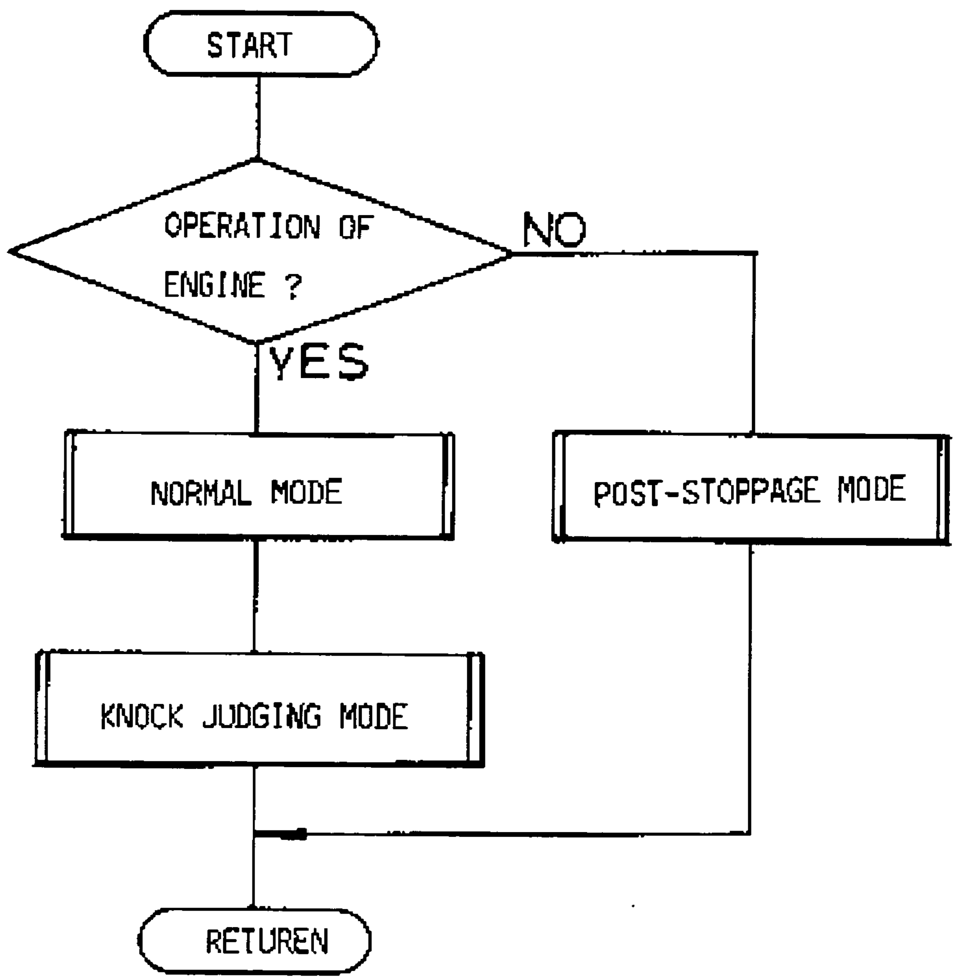

START
OPERATION OF ENGINE ?
NO
YES
NORMAL MODE
POST-STOPPAGE MODE
KNOCK JUDGING MODE
RETUREN

FIG.13

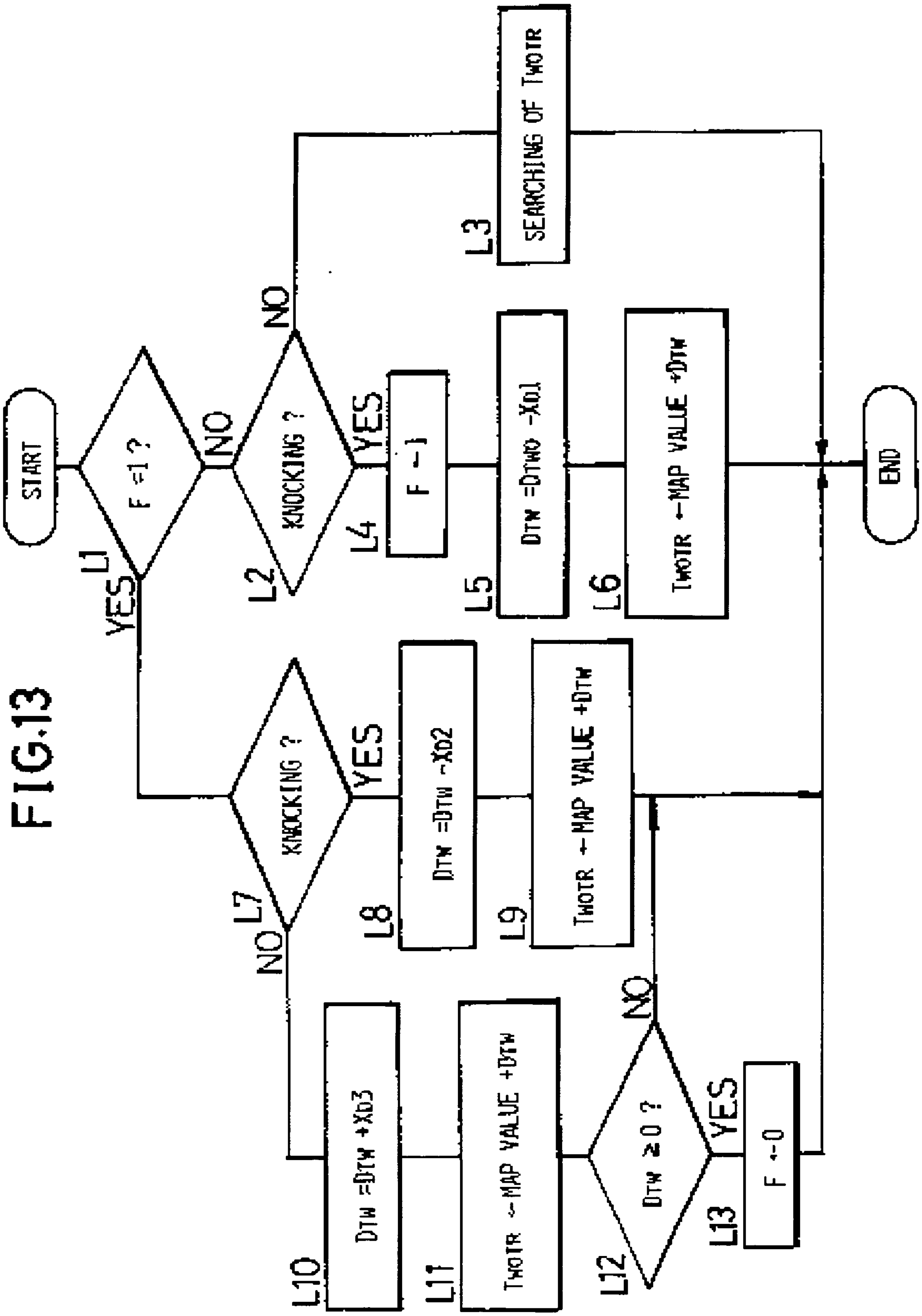

START
F =1 ?
L1
YES
NO
KNOCKING ?
L2
NO
YES
L3
SEARCHING OF TWOTR
L4
F ←1
L5
DTW =DTWO -XD1
L6
TWOTR ←MAP VALUE +DTW
END
L7
KNOCKING ?
YES
NO
L8
DTW =DTW -XD2
L9
TWOTR ←MAP VALUE +DTW
L10
DTW =DTW +XD3
L11
TWOTR ←MAP VALUE +DTW
L12
DTW ≥0 ?
NO
YES
L13
F ←0

FIG.14

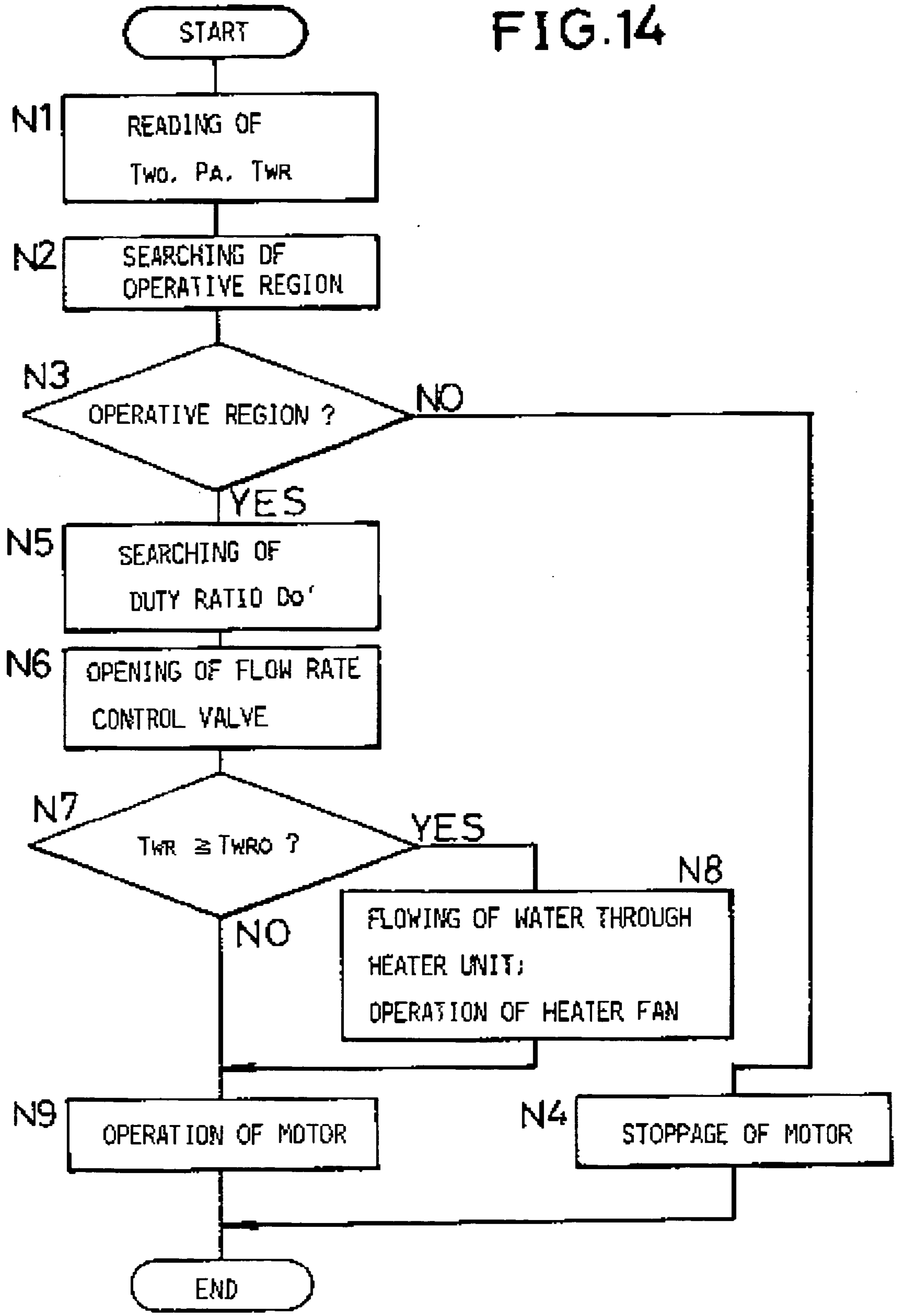

START
N1
READING OF
Two, PA, TWR
N2
SEARCHING OF
OPERATIVE REGION
N3
OPERATIVE REGION ?
NO
YES
N5
SEARCHING OF
DUTY RATIO Do'
N6
OPENING OF FLOW RATE
CONTROL VALVE
N7
TWR ≧ TWRO ?
YES
NO
N8
FLOWING OF WATER THROUGH
HEATER UNIT;
OPERATION OF HEATER FAN
N9
OPERATION OF MOTOR
N4
STOPPAGE OF MOTOR
END

FIG.15

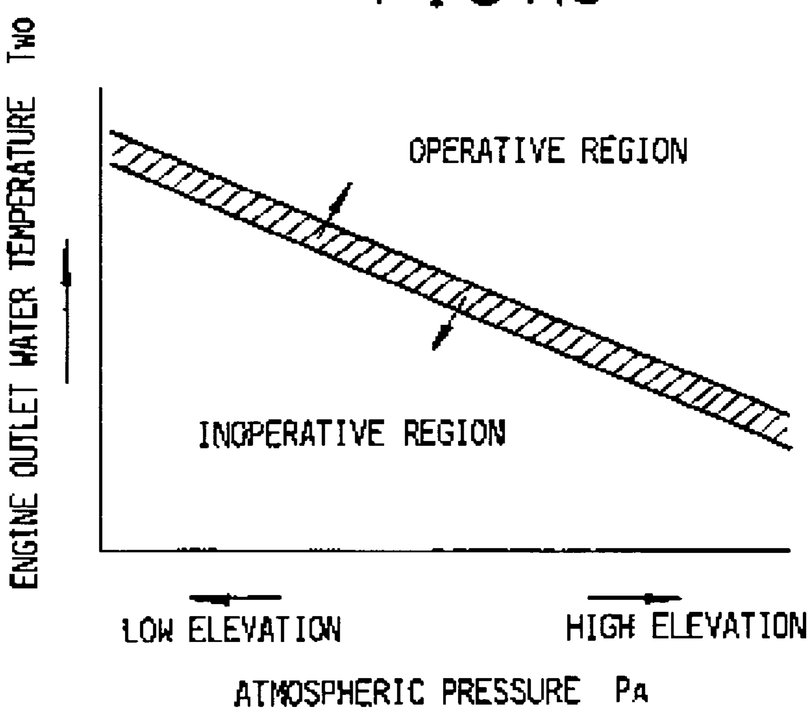

ENGINE OUTLET WATER TEMPERATURE Two
OPERATIVE REGION
INOPERATIVE REGION
LOW ELEVATION
HIGH ELEVATION
ATMOSPHERIC PRESSURE Pa

FIG.16

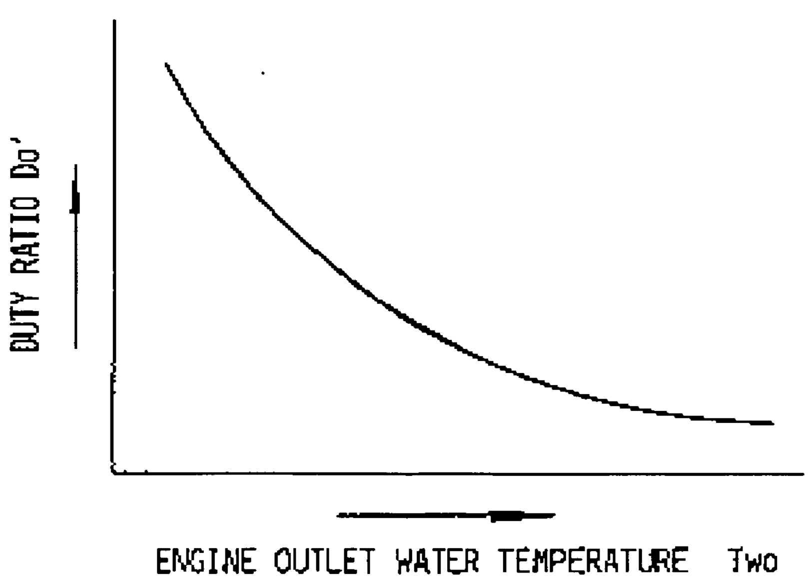

DUTY RATIO Do'
ENGINE OUTLET WATER TEMPERATURE Two

FIG.17

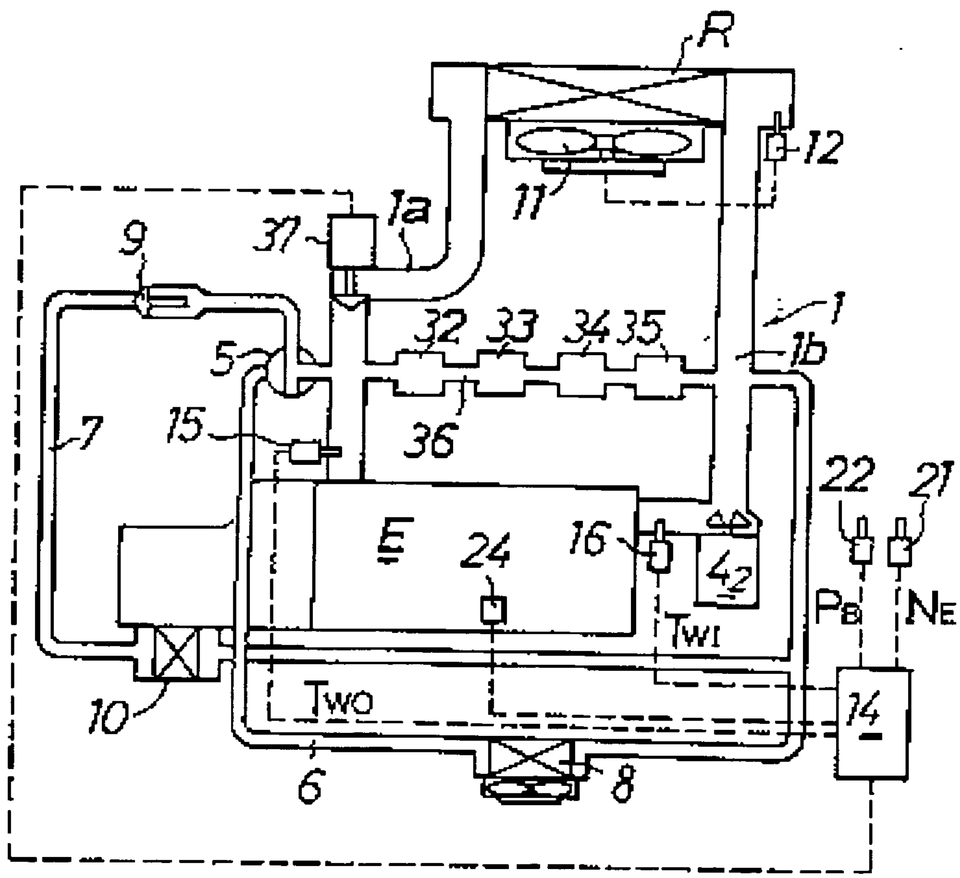

R
12
11
1a
37
9
1
32 33 34 35
1b
5
7
15
36
22
21
E
24
16
42
PB
NE
TWI
14
TWO
10
6
8

FIG.18

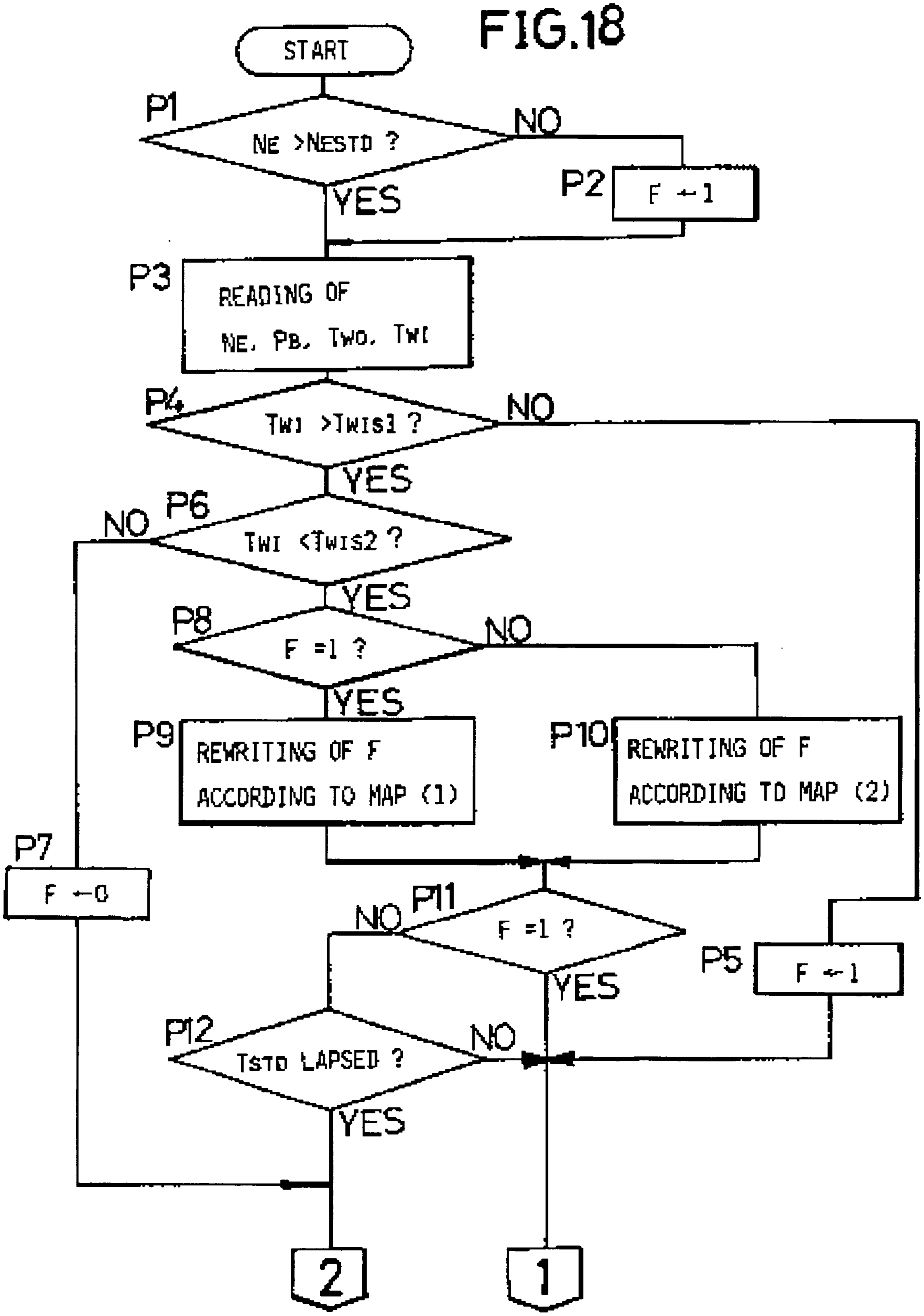

START
P1
NE >NESTD ?
NO
YES
P2
F ←1
P3
READING OF
NE, PB, TWO, TWI
P4
TWI >TWIS1 ?
NO
YES
P6
NO
TWI <TWIS2 ?
YES
P8
F =1 ?
NO
YES
P9
REWRITING OF F
ACCORDING TO MAP (1)
P10
REWRITING OF F
ACCORDING TO MAP (2)
P7
F ←0
P11
NO
F =1 ?
YES
P5
F ←1
P12
TSTD LAPSED ?
NO
YES
2
1

FIG.19

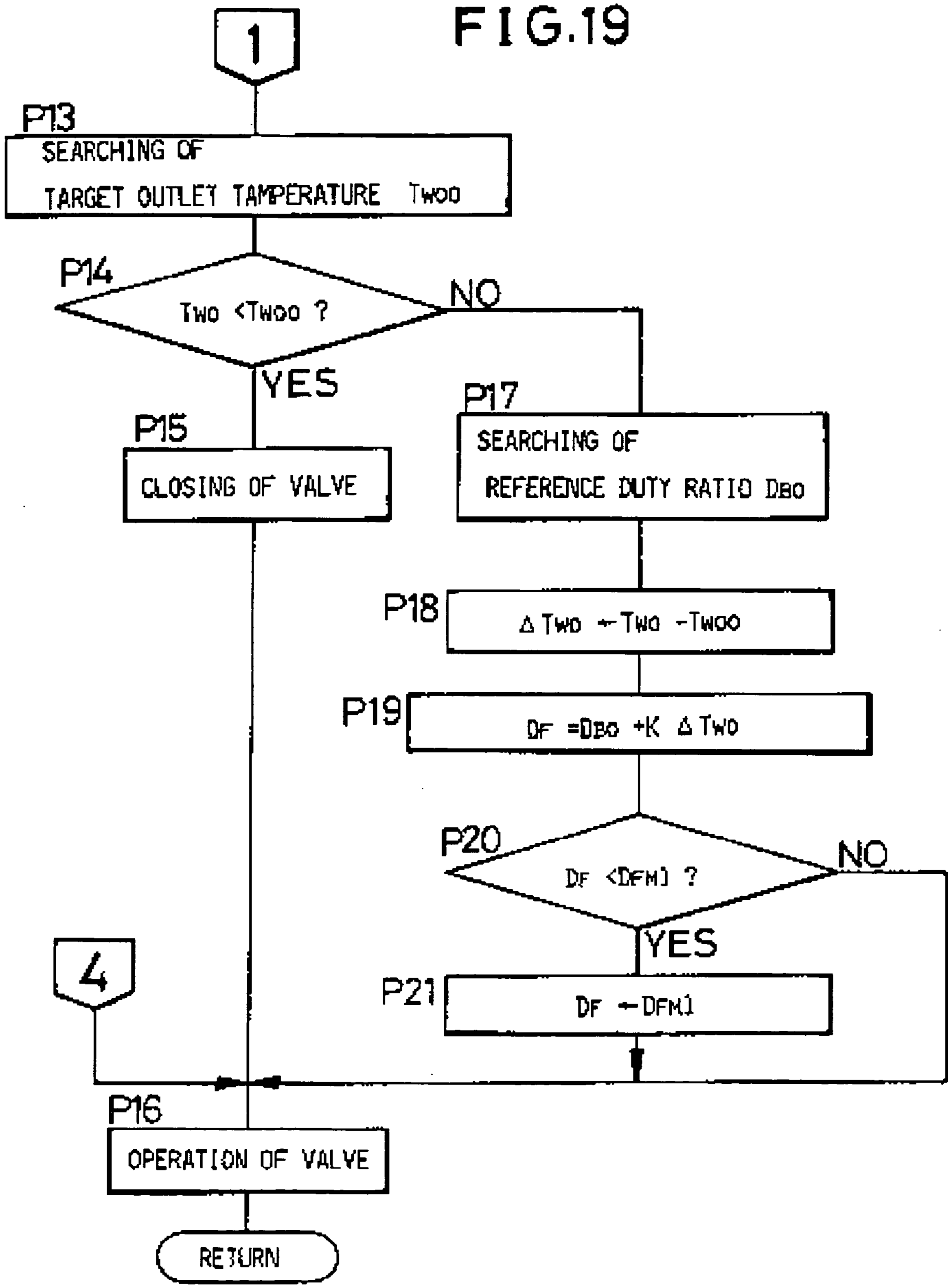

1
P13
SEARCHING OF
TARGET OUTLET TAMPERATURE TWOO
P14
TWO <TWOO ?
NO
YES
P15
CLOSING OF VALVE
P17
SEARCHING OF
REFERENCE DUTY RATIO DBO
P18
Δ TWO ← TWO - TWOO
P19
DF = DBO + K Δ TWO
P20
DF <DFM1 ?
NO
YES
4
P21
DF ← DFM1
P16
OPERATION OF VALVE
RETURN

FIG.20

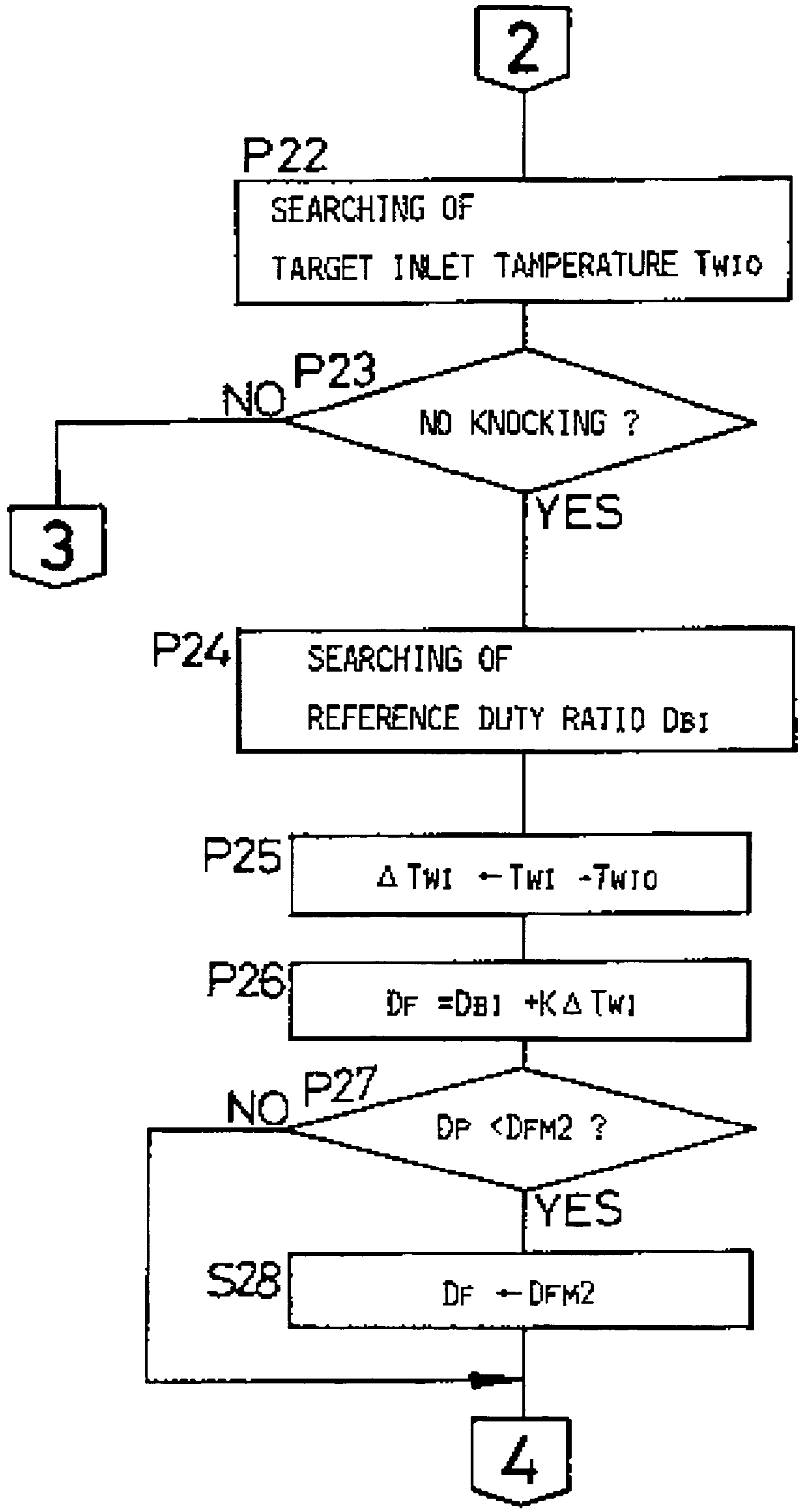

2
P22
SEARCHING OF
TARGET INLET TAMPERATURE TWIO
P23
NO
NO KNOCKING ?
3
YES
P24
SEARCHING OF
REFERENCE DUTY RATIO DBI
P25
ΔTWI ←TWI -TWIO
P26
DF =DBI +KΔTWI
P27
NO
DF <DFM2 ?
YES
S28
DF ←DFM2
4

FIG.21

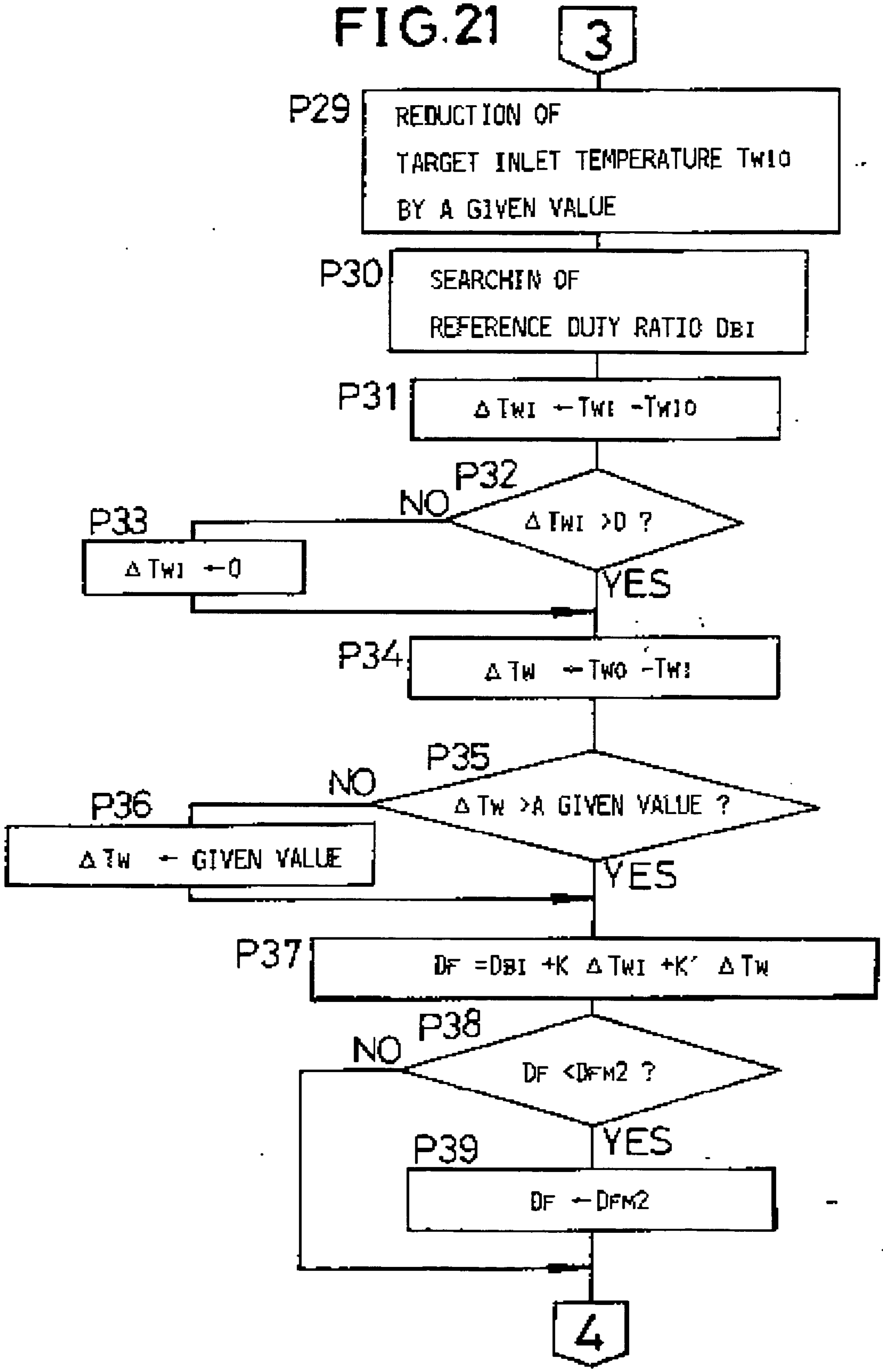

3
P29
REDUCTION OF
TARGET INLET TEMPERATURE TWIO
BY A GIVEN VALUE
P30
SEARCHIN OF
REFERENCE DUTY RATIO DBI
P31
ΔTWI ← TWI − TWIO
P32
NO
ΔTWI >0 ?
YES
P33
ΔTWI ← 0
P34
ΔTW ← TWO − TWI
P35
NO
ΔTW >A GIVEN VALUE ?
YES
P36
ΔTW ← GIVEN VALUE
P37
DF =DBI +K ΔTWI +K′ ΔTW
P38
NO
DF <DFM2 ?
YES
P39
DF ← DFM2
4

FIG.22

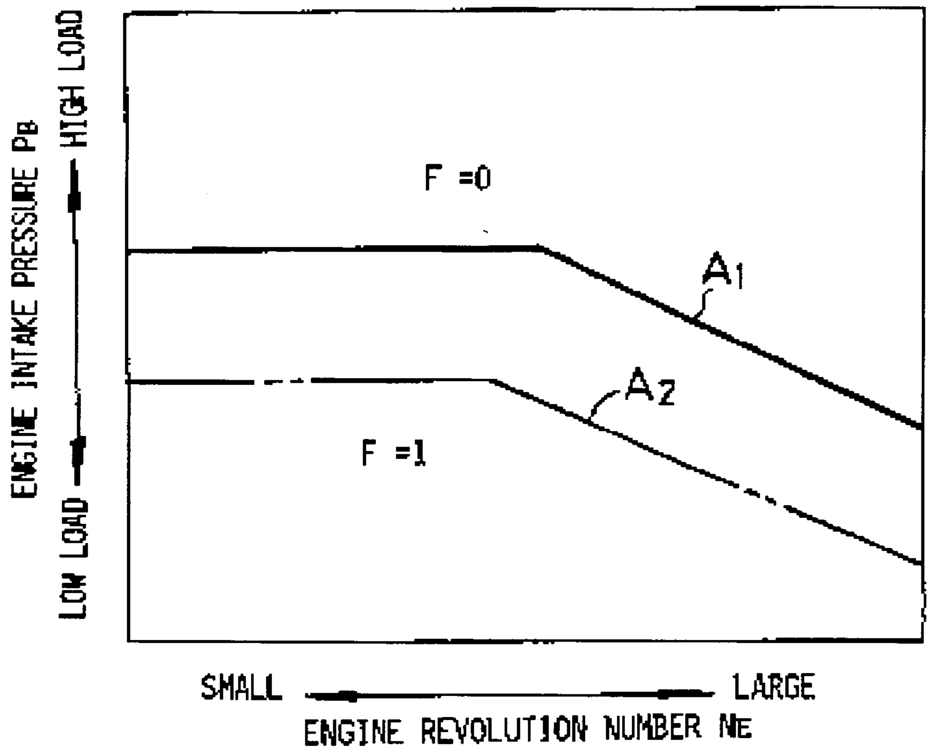

ENGINE INTAKE PRESSURE PB
LOW LOAD
HIGH LOAD
F =0
A1
A2
F =1
SMALL
LARGE
ENGINE REVOLUTION NUMBER NE

FIG.23

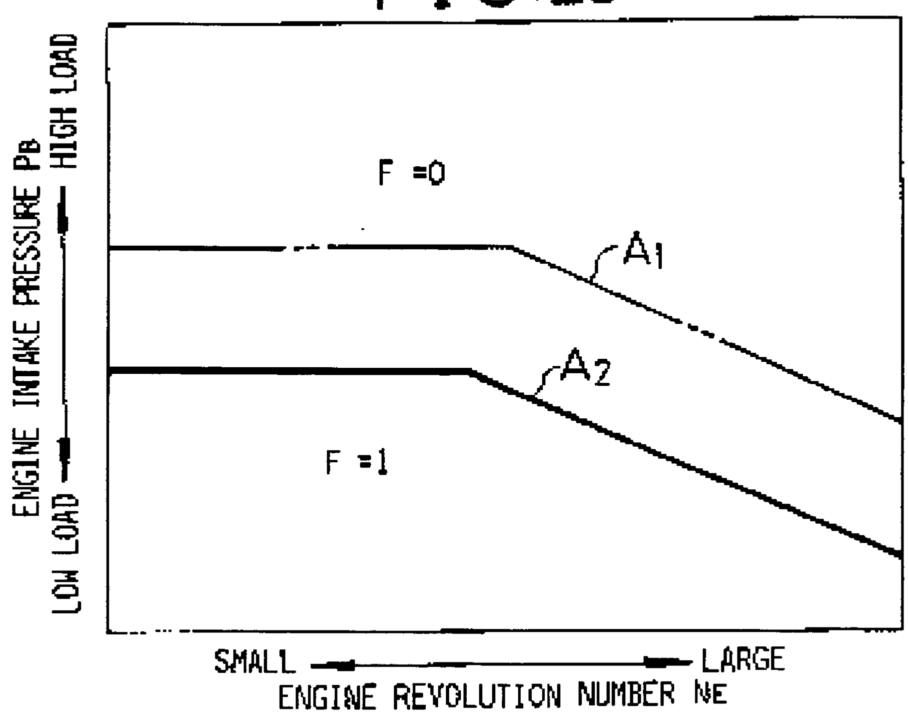

ENGINE INTAKE PRESSURE PB
LOW LOAD
HIGH LOAD
F =0
A1
A2
F =1
SMALL
LARGE
ENGINE REVOLUTION NUMBER NE

FIG. 24

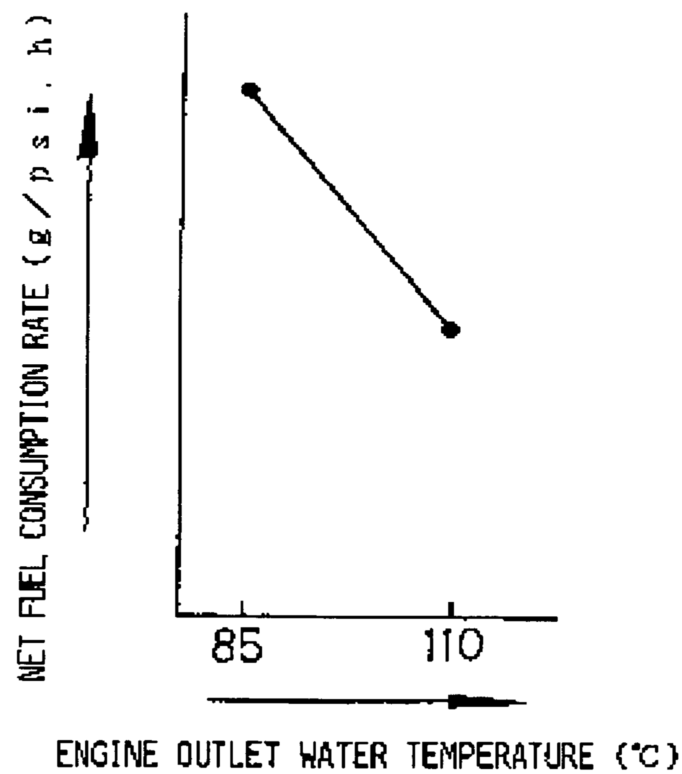

NET FUEL CONSUMPTION RATE (g/psi.h)
85
110
ENGINE OUTLET WATER TEMPERATURE (℃)

FIG. 25

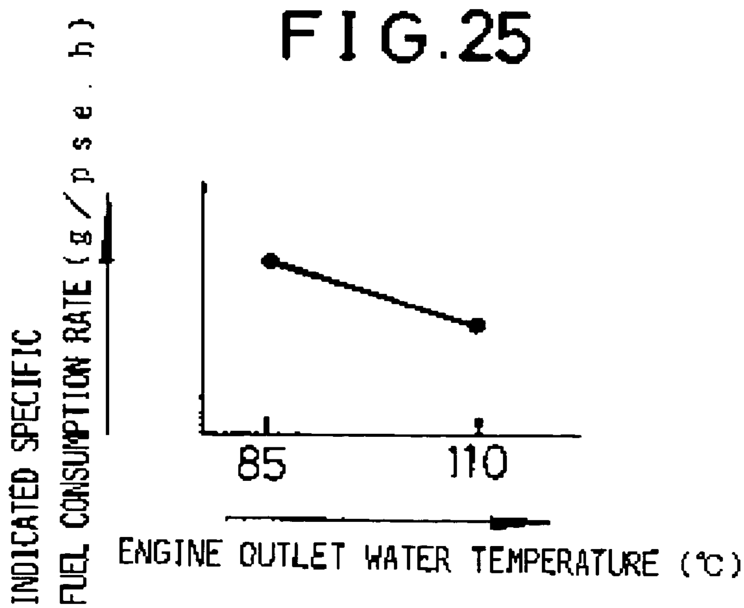

INDICATED SPECIFIC
FUEL CONSUMPTION RATE (g/pse.h)
85
110
ENGINE OUTLET WATER TEMPERATURE (℃)

FIG. 26

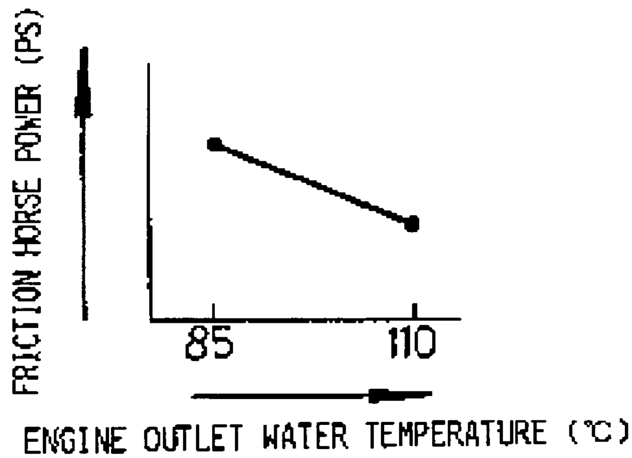

FRICTION HORSE POWER (PS)
85
110
ENGINE OUTLET WATER TEMPERATURE (°C)

FIG. 27

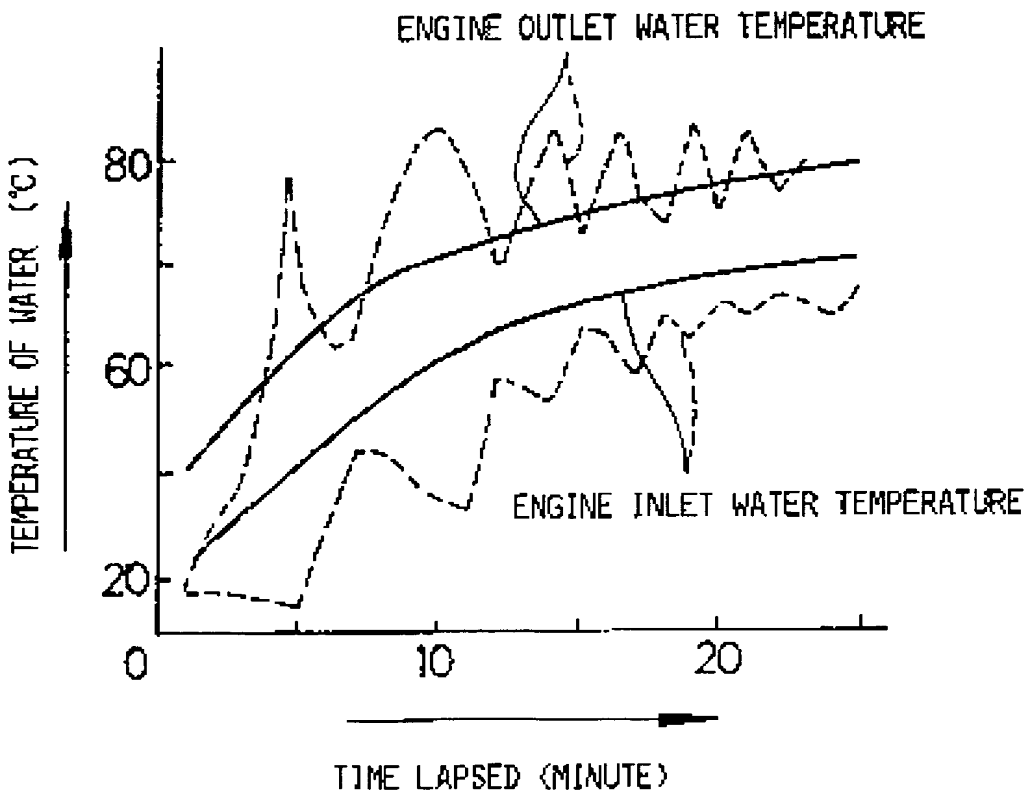

ENGINE OUTLET WATER TEMPERATURE
TEMPERATURE OF WATER (°C)
80
60
20
0
10
20
ENGINE INLET WATER TEMPERATURE
TIME LAPSED (MINUTE)

FIG. 28

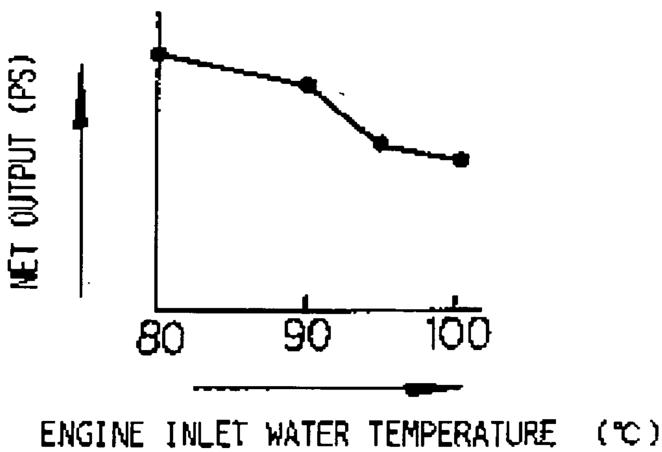

NET OUTPUT (PS)
80
90
100
ENGINE INLET WATER TEMPERATURE (℃)

FIG. 29

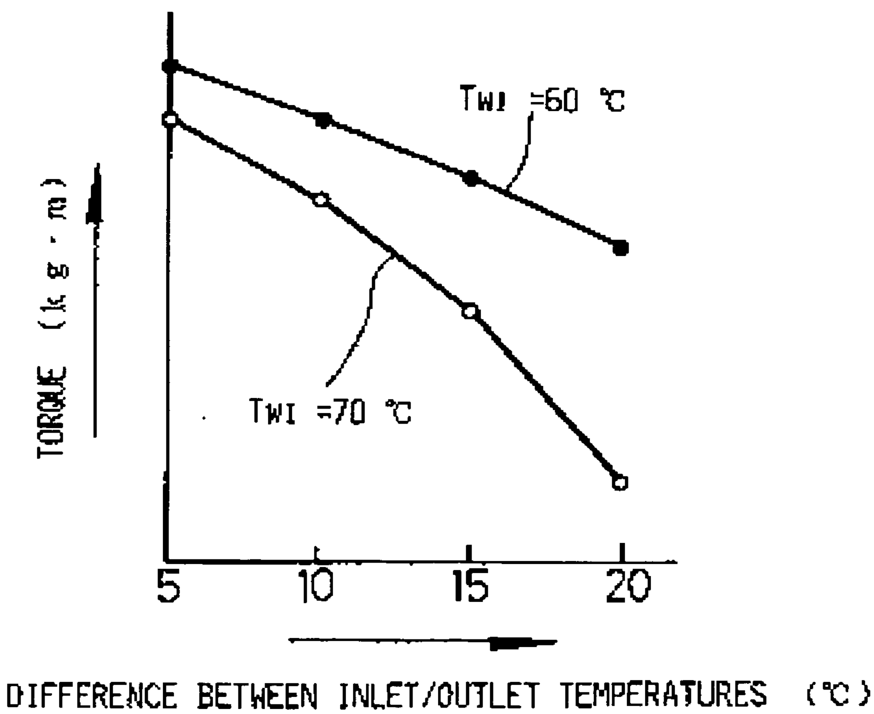

TORQUE (kg · m)
TWI =60 ℃
TWI =70 ℃
5
10
15
20
DIFFERENCE BETWEEN INLET/OUTLET TEMPERATURES (℃)

FIG.30

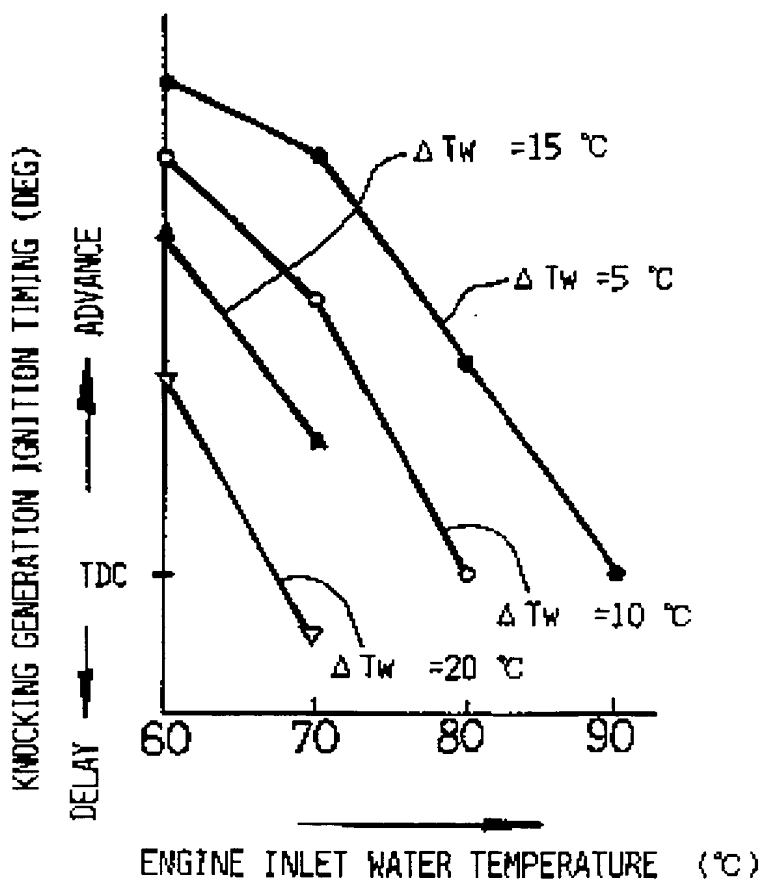

KNOCKING GENERATION IGNITION TIMING (DEG)
DELAY
ADVANCE
TDC
ΔTw =15 ℃
ΔTw =5 ℃
ΔTw =10 ℃
ΔTw =20 ℃
60
70
80
90
ENGINE INLET WATER TEMPERATURE (℃)

FIG.31A

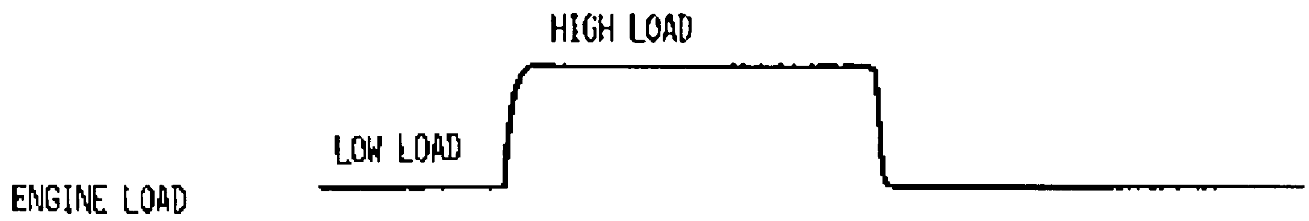


FIG.31B

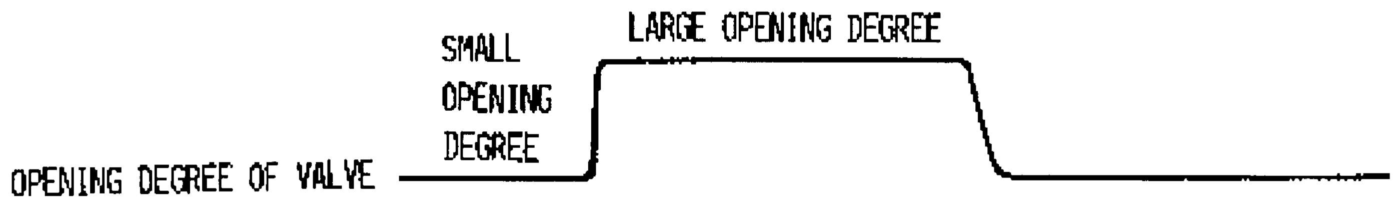


FIG.31C